GEOLOGICAL SURVEY OF NEW JERSEY.

Annual Report

OF THE

STATE GEOLOGIST

FOR THE YEAR

1896

TRENTON, N. J.:
MACCRELLISH & QUIGLEY, STATE PRINTERS, OPPOSITE POST OFFICE.
1897.

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ERRATA.

Page 41, 3d line, read *macroscopical* instead of "microscopical."
Page 118, 8th line, read *forty* instead of "four."
Page 140, 4th line, read *Spruance* for "Spuance."
Page 151, 13th line, read *Bay Head* for "Mantoloking."
Page 176, 24th line, read *Actinocyclus* for "Actinocychus."
Page 180, last line, read *185* instead of "133."
Page 207, 7th line from the bottom, read *complanatus* for "complanatu."
Page 261, 9th line, read *Plate 19* for "Fig. 1."
Page 261, 10th line, read *Plate 20* for "Fig. 2."
Page 332, 17th line, read *tailings* for "tailing."
Page 333, 8th line from bottom, read *low prices now prevailing* instead of "low price now," etc.
Plate XXIV, opposite page 339, read *Arcachon* for "Arcadeon."
Page 359, 5th line, read *Hugues* for "Hugue."

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*Deceased.

To His Excellency John W. Griggs, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to present herewith the Annual Report of the Geological Survey for 1896.

Respectfully submitted,

JOHN C. SMOCK,

State Geologist.

TRENTON, N. J.,

November 30, 1896.

1896.

Administrative Report.

The results of the work of the Geological Survey for the year 1896 are presented in this annual report, and in the administrative part the more general statement of the progress made and of the more important data collected is given, preceding the special reports of the several divisions of the Survey as now organized.

The survey of the surface formations is in charge of Professor R. D. Salisbury; that of the Red Sandstone or Newark formation is being carried forward by Dr. H. B. Kümmel; the study of the crystalline rocks of the Highlands is being continued conjointly by the United States Geological Survey and the State Survey; the supplemental studies of stream-flow and the general topographic surveying are directed by C. C. Vermeule, topographer of the Survey; the forest-survey observations in the southern part of the State are in charge of Gifford Pinchot; the subject of water-supply from artesian wells is reported by Lewis Woolman; the sale of the topographical maps and the financial accounts are attended to by Irving S. Upson.

SURFACE GEOLOGY.

The survey of the surface formations has for its leading objects the determination of the areas occupied by them, or their mapping in detail, so that a complete geological map of the State may be made; the study of the nature of the deposits forming the surface and of their structural relations to one another; and the careful description of the location and extent of materials of economic importance to be given in a full report illustrated by the geological map. This work on the surface geology was begun in 1891. It has been directed by Professor Salisbury, assisted by geological workers trained by him in the field, and the results have been of a character evidencing the advan-

tages of the uniformity in the direction of the work throughout its whole course and over nearly the whole surface of the State. The importance of a detailed map and the advantages of such a survey have been referred to in the administrative reports during its progress. The work in 1896 has been in the eastern part of Monmouth county, and in the southwestern part of the State, in Camden, Gloucester and Cumberland counties. The geological mapping in the latter district has covered the Camden and Woodstown sheets of the new atlas scheme, and also the sheet lying west of Bridgeton, and in general may be said to have covered the belt of rich land along the Delaware and as far eastward as the more sandy and wooded districts of the southern interior. In Monmouth county the study of the underlying and older beds of Cretaceous age in order to the identification of the newer surface formations has taken a great deal of time, and the progress in a real mapping has been slow. The survey of the surface has thrown some light on the structure, relations and subdivisions of the older formations. The larger part of the more fertile portion of Monmouth county, south to a latitude of 40° 30′ has been mapped. The more complex part of the work on the surface geology is done, and that involving the necessity of greater detail, and therefore more time in doing it, and the progress in the remaining portion of the southeastern part of the State can be more rapid.

The results of the work on the Surface Geology have been given in part in the several annual reports for the years 1891–1895, but without maps, excepting for illustration of special features, as the terminal moraine, extra morainic drift, lake Passaic, ice-marks on the Palisades mountain, and other local phenomena, and one atlas sheet—No. 6—which was published in the annual report for 1894. The last named map shows the scope of the survey of the surface formations and the extent of detail given by the geological map which is proposed for the State. The new atlas-sheet has twice as many sheets as the topographic atlas, and the arrangement is such that, by groups of four and six sheets, the characteristic and related districts of the State can be shown on larger maps. The publication of the geological maps of the new atlas has not been begun. The work has been deferred until the report could be prepared which they are to accompany and illustrate. In the meantime, Professor Salisbury is preparing a volume on the Physical Geography of the State, which is introductory to the final report on the Surface Geology. This publication is already, in part,

printed, and a map of the State, on a scale of three miles to an inch, showing the relief of the surface, to accompany the work, has been printed. The preparation of the full report on the Surface Geology is to be begun next year, and some of the maps are to be gotten ready for engraving early in 1897. The publication of this work is necessarily expensive, on account of the number of maps and the detail required to show the intricate nature of the surface formations, although the base is already done in the original topographic atlas-sheets. The making-up new transfer-sheets is comparatively simple and inexpensive, but the representation of so many formations involves the necessity of preparing many new stones and as many impressions on the base. Inasmuch as the preparation of the report, consisting of two octavo volumes, with the text illustrated with many letter-press figures and inset-plates, will require a long time, the large cost involved in the preparation and publication of the maps may be distributed through two or three years at least, and the completion of the geological map be delayed that length of time.

During the year Professor Salisbury was in the field from the first of April to the end of June. His assistant, G. N. Knapp, was engaged in tracing the formations and studying their relations with the older beds, from about the first of April to the latter part of November.

Professor Salisbury gives in his report further information on the distribution, constitution, structure and origin of the Pensauken formation in the northeastern part of Middlesex county and particularly in the vicinity of Metuchen, in the northeastern part of Monmouth county, and in the Mount Pleasant range of hills from the Navesink Highlands to Freehold. Some general statements on the correlation and on the formation, as it occurs in Philadelphia and vicinity, also are given in this report. The more mixed nature of the material, and the presence of red shale and sandstone, and some granitic pebbles, as also the arkose sand, distinguish this formation from the more quartzose gravels of the Beacon Hill formation. The greater development of the latter in the Mount Pleasant range of hills also is notable, particularly in the gravel-caps of this range of hills. The gravel-capped hills of South Amboy, Sayreville and Ernston, in Middlesex county, belong to the Pensauken. The existence of remnants of the Beacon Hill formation in the eastern part of Monmouth county, on isolated hills, shows how large a part of this

once more or less continuous deposit has been removed, whereas to the south, in the southeastern part of the county, it is still an almost continuous formation. The presence of a fine, fluffy sand and a clay, under the gravel and gravelly-sand, heretofore recognized as distinctively Beacon Hill, is stated in this report, and is indicative of a wide range of conditions in the original deposition, from a quiet stage at its beginning to a coarse gravel at the close. The Hominy Hills district appears to show the local development of the fine sands and the clay.

The report has an interesting section on the terraces or terrace-like flats along the Raritan river and southeast in the vicinity of Matawan and Keyport, and also Red Bank, and along the Navesink and Swimming rivers, and refers them to a submergence of the land after the Pensauken time. These flats are at an average height of 40 feet above tide level. Some higher terraces in the Mount Pleasant hills and in the southwestern part of the State are apparently of the same age, as are also the Philadelphia brick-clays, which lie on the Pensauken formation and on the gneiss in that city and in the valley of the Delaware from 30 to 150 feet above tide-level.

The survey of the surface formations has discovered evidences of great changes of level, and submergences of large areas in the southern part of the State, alternating with uplifts when the land stood as high or higher than it does now above the sea. The submergences were marked by the deposition of materials, as clays, sands, gravels, and cobble-stones and bowlders; the uplifts by the wearing-down of the land by stream action. The history of these changes is an interesting chapter in the geology of the State, as now nearly all worked out by the study of these later formations.

The distribution of gravels available for road material is an important part of the economic results of the survey, and the notes on the occurence of gravels in the northern part of Monmouth county, and also in the southwestern part of the State, make one section of Professor Salisbury's report. They are supplementary to the section on road material in the annual report for 1894. The maps show the distribution of these road materials. Since the amendment to the State road law, whereby State aid is given for gravel roads, the importance of a knowledge of the gravel localities is noteworthy, although their large use must remain for the many public and private roads where State help cannot be had. The excellence of the common roads in many places in the southern part of the State is owing to a liberal use of

gravels. If some binding-material, as iron oxide with lime, could be had cheaply, so as to make, as it were, an artificial stone or cemented sand-rock, like that of some of the stone in the gravel-capped hills, the use of these gravels might be increased almost indefinitely.

RED SANDSTONE—TRIASSIC.

The survey of the Red Sandstone or Newark formation, and known generally as the Triassic, which was begun last year, has been carried forward steadily during the field-season of 1896.

Dr. H. B. Kümmel has been occupied almost exclusively with field-work. He has not had any assistants. He began work on the 7th of April, and was engaged until September 10th. He studied in detail that part of the formation lying southwest of a line from Metuchen through Plainfield to Peapack. It was found necessary to make observations on all the outcrops and plot the dips and strike of the rocks on large-scale maps in order to discover the nature of the rocks and their relative position, the thickness of the subdivisions and the faults traversing the formation. All the roads were traveled, and section lines along nearly all the streams were examined. It was slow work, but the results have justified the method. The subdivision of the Newark formation into three well-marked groups of rocks, and the determination of the limits of these groups, is an important advance and a contribution to geologic science. It helps to explain many features of the surface recognized, but up to this time not understood, and the occurrence of valuable building-stone among other facts of economic value is made clear by the recognition of this three-fold division. Several well-marked lines of faulting have also been discovered and have been located on the map. The successful work in the southwestern half of the belt leads to the natural conclusion that a like careful study of the northeastern part will yield equally important results, and in a new geological map the divisions will be shown extending across the State, and their relations to the economic resources of the whole belt be explained. The importance of the work, in its present stage of progress, in the interesting contribution to geology is enhanced by the fact that nearly one-half of the population of the State is residential on the red sandstone belt. Another field-season will suffice to complete the survey. Some of the results are given in the report by Dr. Kümmel, but a large part is reserved for a full report at the end of the next year.

REPORT ON ARCHÆAN GEOLOGY.

Dr. J. E. Wolff, of Harvard University, in his report gives some interesting and suggestive notes on the eruptive rocks of Sussex county, and in particular the syenitic rocks of Beemersville. The occurrence of these strange-looking, crystalline rocks, and the altered slates in contact with them, has attracted the attention of students of geology and practical men, but no suggestion as to their value or economic uses has heretofore been made in reports on them. Dr. Wolff refers to the fresh-looking nature of the mineral composition when studied in thin slices under the microscope, the beauty of the massive rock, and its adaptation to use as a constructive material. Its apparent durability and toughness and its hardness are valuable features. The situation is favorable to quarrying work. The locality is not near railroad, being five miles west of Deckertown, and about the same distance from Papakating, on the New York, Susquehanna & Western Railroad, but the transportation by teams over a good road with easy grades need not be a serious obstacle to the development of a quarry of high-class stone. These eruptive rocks are all well adapted to road-building, and in the absence of other good stone for Telford or stone roads they have importance as sources of road material.

The several localities are shown by a map which accompanies the report.

REPORT ON THE TRAP-ROCKS.

An engagement was made with Professor Joseph P. Iddings, of the University of Chicago, early in the season, to examine the trap-rocks of the State and make a report on them. Professor Iddings visited the quarries and principal exposures of these rocks in the Watchung mountain range from Oakland, north of Pompton, as far south as Plainfield, and west to Bernardsville and Livingston. The relations between the trap and the underlying sandstone, and the evidences of the extrusive character of the trap, were investigated, and specimens of the rocks for microscopical study were collected, but the information thus gathered is not yet ready for making up in a report. It is hoped that after another season the results of the survey may be presented in the annual report.

ARTESIAN WELLS.

Mr. Lewis Woolman has continued to collect all available facts about artesian and deep-bored wells, and has given them in his report for the year. The large number of wells shows the increasing use of this system of water-supply and the successful results of the borings for water, particularly in the southern part of the State. As has been said in these annual reports, the system is capable of great extension, and is limited by the number of localities only. The multiplication of wells in close proximity to one another in some places is suggestive of ultimate failures when the drain from the water-bearing beds shall have reached the point of partial exhaustion of the available supply, but there are not as yet any examples of serious interference in the wells, nor any entire failures or cases of exhaustion. From the thickness of some of the deeper beds which are now furnishing large volumes of water, and from the more or less porous condition of all of the beds of the later formations of the southern part of the State and the easy passage of water downwards from the surface, there is little possibility of such exhaustion, or at least not until the wells have a much greater capacity than they now have. It is possible to estimate the supply within a given bed or beds of sand, and to ascertain the limit for the wells which may draw therefrom. The data for the solution of problems of this kind are at hand, and they indicate that there is little danger at present of any failures on account of the exhaustion of the supply. The shallow wells which draw from comparatively thin beds and near the surface are exposed to the danger of pollution from the surface-waters, and do not have so large reservoirs or sources of supply. The history of these wells in New Jersey is, however, not suggestive of alarm from this cause, but of caution and regard to the surface in thickly-populated districts, or within city limits, that there be no possible contamination by means of polluted surface-waters reaching the well-supplies. The deep-bored well is so well suited to many localities for local water-supply that the attention of parties seeking new sources is asked to the report of Mr. Woolman as evidence of what may be had. The report includes a great deal of information given by firms engaged in boring wells, and the Survey is greatly obliged to these firms who have thus contributed valuable records for this publication.

A part of Mr. Woolman's report is given to geological notes on the

clays, sands and gravels which are exposed in the clay workings at Fish House, and to records in detail of borings made there and at Delair, northeast of Camden and nearly opposite Philadelphia. Full reference to geological notices of the fossils which have been found at Fish House are included in his report, and they show how much has been published on these clays and their fossil contents and their age. The importance of the determination of the age of the Fish House clays and of their relation to the other formations in the Delaware River valley is appreciated by all students of geology. The older white and red plastic clays of Cretaceous age are well exposed at the clay banks on Pensauken creek, within a mile northeast of Delair, and also the Pensauken formation, so that there is a great deal of geological interest in this little district between the above-named creek and Fish House, and it is so readily accessible from Camden, Trenton and Philadelphia that it is worthy of particular notice. The borings show extensive beds of valuable clays, which are already dug largely, and the map which accompanies Mr. Woolman's report presents graphically the extent of these beds, their position and their nearness to transportation lines and to market. The details of the borings are a valuable record for future working, and to all students of geology who may wish to explore more in detail and study the relations of the several beds of this unique geological district.

In addition to the Fish House clays Mr. Woolman describes a remarkably large Saurian bone, found near Merchantville, and the silicified trunk of a giant conifer uncovered in a sand-bed near Lindenwold, in Camden county. These recent interesting discoveries in our old settled and apparently well-explored districts of the State are stimulating to persevering and careful searches and suggestive of valuable results to all who are faithful and diligent in pursuing their explorations.

DRAINAGE.

The Geological Survey is authorized by law to make surveys and plans for the drainage of tracts "subject to overflow from freshets, or which are in a low, marshy, boggy or wet condition," whenever application is received from at least five owners of separate lots of land in any tract which it is proposed to have drained. Under the general drainage laws, as amended by supplementary acts, these provisions of the law are applicable to tide-marshes also.

The Great Meadows, in the Pequest valley, have been improved in accordance with the provisions of the drainage laws, and the practicability of the legislation demonstrated. The maintenance of the improvement by clearing the channel of the Pequest river and the extension of a system of lateral ditches, was referred in the last annual report.*

The Passaic drainage work was also referred to in the same report. The general depression of business and the unsettled financial condition of the country made the sale of bonds impossible, and the work was suspended on account of a lack of means for carrying it forward to early completion. The suspension of the work of drainage bears heavily upon the holders of the bonds, and tends to discourage the farmers in the valley who have been looking to the drainage as a relief from the losses caused by the floods. It is also discouraging to similar enterprises elsewhere.

It is not necessary to re-state the argument for the reclamation of these wet lands in the upper Passaic valley. The importance of the work is enlarged with the growth of the towns on the borders of this valley and the consequent greater necessity for the removal of these malarial influences, and with the enhanced value of the lands immediately affected by the projected improvements. The effect of the drainage upon the quality of the water which is now used by the city of Paterson is another important argument for the early completion of the work. It is hoped that the commissioners may be enabled, by the sale of an additional volume of bonds, to get the necessary means to secure the result.

TOPOGRAPHIC WORK.

The report of Mr. C. C. Vermeule, Consulting Engineer, is given in two parts, one on the Hackensack and Newark tide-marshes, the other on floods in northern New Jersey and stream-flows. The high floods in the northern part of the State, in February, afforded excellent opportunities for studying the rate and volume of discharges of these streams under remarkable conditions. These studies are supplementary to the Report on Water-Supply, published as Volume III of the "Final Report" series. This flood of February 6th was extraordinary, on account of the frozen ground, the accumulated snow, the

*An. Rep. State Geologist for 1895, page xx.

heavy rain and sudden melting, and the consequent rapid discharge of the waters, swelling the streams to a height in some cases surpassing any ever before recorded, and causing a large loss of property and serious inconvenience to travel. Advantage was taken of these conditions and occurrences to collect all available facts as to height of water, length of the flood and results of flooding, and to the study of their relations to the topographic features of the several water-sheds, and in particular, the influence of forested conditions upon floods of this kind. The observations and investigations of Mr. Vermeule show that "forests do not diminish to an important extent the height of extreme high floods, but do materially diminish the number of floods." The forests tend to equalize the flow of the streams. They also prevent roiliness of the water. The comparative studies of the more wooded Passaic water-shed, and the largely deforested valley of the Raritan, show that the forests in this flood exercised very little influence in retarding the sudden rush of water due to the melting of comparatively deep snow by a heavy, warm rain, on frozen ground. The whole northern part of the State was covered, as it were, by a sheet of water which could not be absorbed to any appreciable extent either by the frozen ground of the fields or the scarcely less receptive humus earth and litter of the forests.

These studies demonstrate the great influence of topographic conditions, as for example that of the Passaic flats and the Great Meadows of the Pequest, as compared with the rapid discharge of flood-waters from the upper part of South Branch, the Musconetcong river, and the tributaries of the Passsaic. The comparison of the Pequannock and the Musconetcong with the South Branch seems to show that topographic conditions are paramount to the influence of forests.

The study of this flood is instructive in its suggestions on the necessity of ample waterways for the discharge of the extraordinary volume of water, and the prevention of losses arising from bridges and embankments which hinder the free flow of streams.

The other important part of the work of the engineer has been the examination of the Hackensack tidal marshes with a view of reaching some practical suggestions for their reclamation. This subject has been referred to in the reports for 1869, and repeatedly since that time.* In

*An. Rep. 1869, pp. 38-40; An. Rep. 1870, pp. 18, 19 and 48-52; 1892, pp. 345-353; and 1895, pp. xxvi-xxvii.

the last report the importance of the reclamation of these meadows was stated in some generalizations as to their value for agricultural uses and the incidental gain to the country from the æsthetic point of view. In the report given this year the subject is discussed with the help of a map of the territory, and with data on the navigable waterways, their depth of water and their value as channels of communication, on the various drainage streams, the nature of the surface and the depth of the mud, on the extent and size of embankments necessary to the protection against overflow, and on the plant requisite for the pumping of the water from the low levels and its discharge into the tidal waterways. The statistics show that reclamation by banking and by pumping out the water is a practicable scheme, and that the cost of the undertaking and of maintenance is not prohibitory.

The reclamation of this broad belt of tide-marsh between the Palisades mountain range on the east and the red sandstone ridge on the west, and intersected by the deep waterway of the Hackensack river, is suggested by these dominating topographic features. The courses of the streams and the bordering ridges indicate the natural plan for the drainage of the waters from the low-lying plain or marsh levels. These drainage channels are also, for a large part of their course, navigable; and therefore, their improvement would be a help to commercial lines and means of access. The permanent improvement of these lands would be the removal of what is now a source of malaria and mosquitoes, and therefore of vital importance to the densely populated uplands on each side of them. The æsthetic gain need not be considered, although of value in the consideration of the residential property in the market, which is more or less affected by nearness to these wet meadows. Perhaps the most effective argument for the reclamation is that thereby these lands cannot be the last refuge of nuisances and the general dumping-ground of whatever the upland territory may not tolerate. The real value of the tidal-meadows improved and in market-gardens alone would be more than enough to pay for the cost of reclamation, but the addition of so much tillable land is of less importance than their value for building-sites and the extent of navigable waterways made accessible to these sites.

The report of Mr. Vermeule shows that the reclamation is practicable. It discusses the methods which are suited to the conditions and the importance of a comprehensive scheme or plan of drainage and

improvement, under a commission charged with the work and with the maintenance of the whole improvement. The existing drainage laws are referred to as adequate, with perhaps a slight amendment relative to the assessments of a part of the costs on the property of the towns and adjacent uplands which are to be benefited indirectly by the removal of the nuisance of mosquitoes, the dangers of malarial disorders arising from these lands in their present condition, and by the general enhancement of values on account of the contiguity of improved lands. It is not an extravagant assertion to make that the reclamation of these 27,000 acres of tide marsh would be the best investment which could be made by the cities of Newark, Jersey City and Elizabeth, and the adjacent municipalities.

NATURAL PARKS AND FOREST RESERVATIONS.

The importance and value of reservations of tracts, marked by their natural features and situation, for purposes of public health and recreation, are appreciated more highly as the population of the cities and the suburban districts of the State increases, and the tastes and the necessities of crowded conditions call for more room and opportunities for the enjoyment of the beauties of natural scenery and for the study of natural conditions as yet uncontaminated or despoiled by the more utilitarian forces of civilization. The State is fortunate in the possession of many large tracts and districts near the cities, which are hardly affected by these agencies and which are well adapted to the purpose of parks and reservations for public use. These may be classified as parks for city use, as reservations whence public water-supplies are obtained, and forest or timber-land reservations. Of the first-mentioned class, which relate more particularly to the larger municipalities, there is little to be said in addition to what has been stated in preceding reports, and the topographical maps have shown the location and approximate areas of wooded districts and possible park sites. The recent surveys for the forestry work of the Geological Survey have made it possible to show on maps of larger scale and in greater detail the wooded districts and tracts in the northeastern part of the State. The Palisades mountain and the Watchung mountains are the more prominent of these available sites for large parks, and comparatively near New York and the cities in the Hackensack and Lower Passaic valleys. As is well known, parks enhance the value

of the real estate of a city, but the acquisition of large areas of land adapted to such use is a subject of wise administration and comprehensive study of conditions, as well as financial consideration, in advance of the movement of population and the destruction of many elements of natural beauty. For further information, reference may be had to these forest surveys, the results of which are to be published in a special report to the Legislature. Reservations for the conservation of public water-supply sources are of importance to the cities in their collective capacity rather than to the individual citizen. The Highlands, as a source of nearly all of the water which is used in the cities of the northeastern part of the State, should be protected against complete deforestation, and also from the clearing of the woodland, which is on the steeper mountain-sides and hills. While it may not be possible, or even desirable, for the State to own any of these areas whence the cities obtain their water-supply, there may be occasion for some restrictive legislation to protect them and keep them in their present wooded condition. To this extent large parts of the Highlands may be, as it were, public reservations, and readily accessible to the inhabitants of the cities, and conducive both in the wholesome water-supply and in the facilities for contact with beautiful natural scenery to the valuable uses of health and pure recreation. In this administrative report it is impossible to make other than these general statements about the Highlands, and to refer to the report on water-supply,* to the topographic maps, and to the forest maps of the Highlands which are to be published at an early date.

The reservation of lands for forest protection and timber culture has also been referred to in the annual reports for the years 1894 and 1895. The divisions of the State where such reservations may be made are three: (1) The southeastern or coastal-plain belt, or what may be called the pines belt; (2) the Highlands; (3) Kittatinny mountain. Inasmuch as the Highlands is regarded as important as a source of water-supply rather than as a forest belt, and as it is already fairly well protected against the ravages of forest fires, it is not properly of importance in this class of public reservations. The Kittatinny mountain belt is comparatively narrow, consisting of the summit and northwestern slope of the same. Although swept by frequent disastrous fires and so exposed to losses of this nature that some protective meas-

* Report on Water-supply, Vol. III. Fin. Rep. State Geologist.

ures are much needed, it will necessarily remain in forest because of its rocky surface and thin and poor soil, which is not adapted to tillage or even economic pasturage. The timber on it is in many parts almost inaccessible, and is not large nor of valuable kinds for market, hence its importance is hardly great enough to demand the intervention of the State and the creation of a reservation. On account of its local importance as the tramping-ground for summer tourists from the Delaware Water Gap, High Point, and other places, its protection would appear to be entirely within the sphere of those who are thus interested and the landowners.

The division of the State which may be justly considered as a forest or timber-land reservation is that of the coastal-plain belt and southeast of the greensand marl. In this part of the State there are nearly 1,000,000 acres of woodland and brushland. Mr. Gifford, in his notes on European forestry methods, has referred to the necessity of public control and State management of the forests for this part of the State. The protection against forest fires has been advocated in these reports,† and the urgent necessity on account of the great losses every year, and the threatened destruction of the whole as a timber-producing district, is almost imperative in the demand for some kind of control which shall protect it and reduce the losses by fires. The Geological Survey is not yet prepared to recommend any specific plan or legislation of any kind until its surveys and studies which are now in progress shall have been completed. It is expected that they may be ready at the end of the next field season, and that the report of the consulting botanist, Mr. Pinchot, may afford the data adequate to a thorough comprehension of the needs of this great forest division, and to its protection and development and the interests of the whole State.

FORESTRY SURVEYS.

The work in forestry has been suspended during the year for want of funds, excepting some local surveys in the valley of the Raritan, made by Mr. Staats, under the direction of Mr. Vermeule. A few days were spent in the autumn in an examination of the forest conditions, and particularly of the extent to which the forest has been removed, and the size and nature of the standing timber left in the few tracts remaining in the Raritan valley. The results of the survey

† An. Rep. 1894, pp. 275–286; An. Rep. 1895, p. 97 *et seq.*

are to be used in making up the report on the forests of the State. Mr. John C. Gifford, who had been employed in the southern part of the State in the forest survey, handed in his report in the early part of the year. That report awaits the further study of forestry conditions and needs, and contains much valuable material for the full report on the subject. Subsequently, Mr. Gifford went to Europe and traveled in Holland, Germany and France, collecting data on forest problems, and making a general study of the subject in its bearings upon conditions in New Jersey. He returned home in November, and the record of his observations in Europe make a part of this annual report of the Survey.

The special investigations which the Survey is making are to be resumed at once, as the appropriation for the work is now available, and Mr. Gifford Pinchot of New York has been appointed consulting botanist to the Survey in carrying out the provisions of the law directing this forestry-work. He is about going into the field, and is preparing to study carefully the conditions in the southern part of the State and the needs for forest protection. So much has been said in these reports about the destructiveness of forest-fires and their discouraging influence against all schemes of reforestation, and their demoralizing tendencies even against mere landownership in the wooded districts of that part of the State, that it is not necessary to report these statements. Reference to preceding reports is sufficient.

It is proposed to carry forward, next year, surveys of the forests, and to present the results and studies in a special report to be made to the Legislature when the work shall have been done. The interesting and suggestive operations on what was seen in Europe by Mr. Gifford are helpful in calling fresh attention to the importance of saving what we have left, and stopping this great, unnecessary, and almost wilful waste of our natural resources.

THE IRON-MINING INDUSTRY.

Mr. George E. Jenkins, of Dover, was engaged in the autumn to visit the iron mines and the zinc mines in the State, and to make a report on the general condition of the iron-mining industry, and on the active mines in detail as to their extent of working, nature and occurrence of the ores, structural relations of the ore-bodies, plant and output for the current year. The prospective revival of business, and

the inquiry after ores, appeared to indicate the time as opportune for a report giving facts which would answer inquiries and call attention to the mines and localities of ore-deposits of the State. The last notice of the iron mines was in the report for 1891. Mr. Jenkins has noted the mines which have been at work since the last report, and at times during this five-year period. The fact that New Jersey has maintained her relative position as an iron-ore-producing State, in comparison with the States of the Atlantic coast and middle and central west, is worthy of note, and is suggestive of the advantages of location, economy of working, and excellence of ores, which characterize the iron mines. In view of a possible demand for ores for foreign shipment as well as for home markets, the mines of the State are advantageously situated on lines of easy and cheap transportation, and with reliable and skilled labor at hand. The report of Mr. Jenkins gives much information on important points of inquiry, and is commended to the attention of capitalists and all interested in the industry.

The statistics of individual mines, and the aggregate production of the State, are given at the end of this annual report.

CHEMICAL LABORATORY.

The chemical work of the Survey has been done at New Brunswick, in the laboratory of Rutgers College. Prof. William S. Myers reports the following list of specimens examined during the year:

One granitic rock tested.
One sample pyrites, Green's lake, Warren county, assayed.
One earth analyzed.
One pyrites specimen, Stockholm, assayed.
One greensand marl, from Holmdel, analyzed.
Clay from Woodstown analyzed.
Iron ore, Stockholm, analyzed.
One limestone, Columbia, analyzed.
Ten shales from Red Sandstone belt,
Three sandstones from Red Sandstone belt, } Analyzed.
One calcareous sandstone from Red Sandstone belt,

The shales and sandstones of the Red Sandstone or Newark Formation were analyzed for the report by Dr. Kümmel, and were for comparative study by means of microscopic sections of the same specimens.

GEOLOGICAL ROOMS.

The collections of the Survey, which are on exhibition in the room of the rear extension building of the State House, remain as at date of last report, excepting the addition of the minerals which were at the Columbian Exposition in Chicago. This collection has been unpacked and put in the table-cases. A few specimens of rock collected during the year also have been put on exhibition.

The room is open daily and an attendant is in charge. The number of visitors is comparatively small, being limited to the ordinary "State House" sight-seeing company.

The consolidation of the collections of the State in a general State museum would probably attract more attention and do good.

PUBLICATIONS.

The publications of the year were the annual report for 1895, and Volume III of the Final Report of the State Geologist, being a report on water-supply. These reports have been distributed widely.

The demand for the publications is increasing from year to year, and the supply in the case of some of the older reports is nearing exhaustion.

The sales of the topographic maps for the year amounted to $450. New editions of Atlas Sheets, Nos. 7 and 11, being the Jersey City and the Camden sheets respectively, have been published since the last annual report was issued. The topographic maps are sold at twenty-five cents a sheet.

STAFF OF THE SURVEY.

PROFESSOR ROLLIN D. SALISBURY is in charge of the survey of of the Surface Formations. He has been assisted by G. N. KNAPP.

HENRY BARNARD KUMMEL, Ph.D., has charge of the surveys of the Red Sandstone or rocks of the Newark System.

CLARKSON C. VERMEULE, consulting engineer and topographer to the Survey, has directed the topographic work on Stream Flows. PETER D. STAATS is assistant.

In co-operation with the United States Geological Survey, Dr. J. E. WOLFF has made surveys in the Archæan rocks of the Highlands. He has been assisted by A. H. BROOKS.

IRVING STRONG UPSON, at New Brunswick, has charge of the sales of maps. He is also the disbursing officer of the Survey.

HATFIELD SMITH is general assistant in the office at Trenton.

PART I.

SURFACE GEOLOGY.

REPORT OF PROGRESS

BY

ROLLIN D. SALISBURY and GEORGE N. KNAPP.

REPORT OF PROGRESS.

BY ROLLIN D. SALISBURY, GEORGE N. KNAPP.

During the Summer of 1896, the senior author of this Report spent about six weeks in the field, and the junior author, about eight months. During this time, detailed work has been in progress in the western portions of Gloucester, Salem and Cumberland counties, and in the northern portion of Monmouth county. With the close of this season, the work in connection with the surface formation, of the State has been essentially completed in all the considerable areas where it seems likely to be profitable to prosecute it in great detail. In the first three counties named, the survey has progressed from the west toward the east, and has been carried to the limit of the generally cultivated area. In northern Monmouth county, the work has progressed from north to south, and has reached the southern limit (lat. 40° 13′) of the area which is under general cultivation. The western portion of Camden, and the northern and western portions of Burlington counties were treated in a similar way previous to the present season, so that from the north and west, work has been pushed south and east, until the area which now remains unstudied, corresponds, in a general way, with the great forest area of the southeastern part of the State. Within this general area, there are some relatively small tracts where the land is under cultivation, and where the state of culture is such that detailed study may be profitable. The most considerable tracts within the region not yet mapped, which are likely to yield results of sufficient value to warrant detailed study, are those about Farmingdale, in Monmouth county; Toms River, in Ocean county; Vineland, in Cumberland county; Hammonton, in Atlantic county; Winslow, in Camden county, and a narrow belt along the coast from Toms River to Cape May, lying in Ocean, Burlington, Atlantic and Cape May counties. The aggregate area which seems likely to demand detailed study is not great. It is anticipated that the progress of the work in the future will be much more rapid than in the past. Indeed, in a very large proportion of the area yet to be studied, little

can be done because of the lack of exposures of all sorts. Furthermore, this area has been reconnoitered, so that its general character is already known, and it seems probable that over much of it the surface geology is simple.

A large body of material concerning the geology of the southern portion of the State has been collected during the season, and a large portion of that which has been collected in the past two seasons has been put in shape for future use. This large body of fact is more appropriate for a final report than for an annual, and will be reserved for such publication.

The accompanying map shows the portion of the State in which the work on the surface formations has been essentially completed.

THE PENSAUKEN FORMATION.

In the annual report for 1895 the general distribution and relations of the Pensauken formation for a considerable section of the State were described, and represented on a small map (Plate I). During the past summer the formation has been further studied in Camden, Gloucester, Salem, Cumberland, Middlesex and Monmouth counties, and its distribution, so far as now known, is shown on the accompanying map (Plate II). The area to the southeast of that on which the formation appears remains unstudied, so far as details are concerned, but enough of the region has been seen to indicate that the same formation which occurs about Glassboro and Bridgeton is widespread in this area.

IN NORTHEASTERN MIDDLESEX COUNTY.

North of the Raritan—Distribution.—North of the Raritan river the Pensauken formation occurs in several localities which now appear somewhat isolated. The largest area which it covers is south and southwest of Metuchen, where it has an extent of three or four square miles. Besides this, it is probably continued to some extent beneath the drift to the northeast. By comparing the map accompanying this report with the topographic map of the State, it will be seen that the formation occupies an area somewhat above its surroundings. It is

indeed the divide between the Mill creek, on the one hand, and Ambrose's brook on the other. The next most extensive area lies just east of Mill creek, and is really separated from the first only by the valley which this creek has developed since the deposition of the Pensauken formation.

Further west, in Somerset county, there are several small patches of the Pensauken which have been referred to in earlier reports. In all cases they cap elevations which are now more or less isolated. Occasional pebbles, which appear to have been derived from the same formation, are scattered widely beyond the limits here indicated, and show that the formation originally extended far to the northwest. The base of the formation about Metuchen has an elevation of a little more than 100 feet on the northwest side of the area where it occurs, but declines to the southeast, to 70 feet or less. The isolated remnants northwest of the Pennsylvania railroad between New Brunswick and Metuchen are somewhat higher than the foregoing.

Constitution.—While in a general way the constitution of the Pensauken of this region is harmonious with its constitution elsewhere, it yet differs in certain notable and yet very significant particulars. To the north it contains much red shale (Triassic) and sandstone. Locally as much as seventy-five per cent. of the stony part of the material is of this sort. It also contains, as does the Pensauken generally along its northern portions, a considerable constituent of granite, or granite-like material, which is uniformly very thoroughly decomposed. Cobbles six inches in diameter are often soft to their centers. To the south, both the shale and the granite material, but especially the former, becomes less abundant. As the shale decreases, sand, sandstone and quartz pebbles, usually very well rounded, appear in greater abundance. The sand is sometimes arkose, but the arkose character is here less notable than south of the Raritan.

Structure and Origin.—The body of the Pensauken was deposited in sea water during submergence of the area where it occurs. The Pensauken of this locality differs in structure from that in many places, in that it is sometimes notably till-like; that is, it is unstratified, and contains a good deal of stony material of large size, and this stony material, in places, bears glacial striæ. The till-like structure and the striated stony material are especially characteristic of the northern portion of the area here considered. This is the only place in which striated material has been found in the Pensauken formation, and the association with till-like structure seems especially significant,

and seems to point to ice as one of the agencies concerned in the origin of the formation, at this locality. This seems the most definite clue which has yet been found pointing to the connection of the Pensauken with an early formation of glacial drift. It has been pointed out in earlier reports that the constitution of the formation, which sometimes contains large boulders, would best be explained, if floating ice could be invoked, but up to this time more definite evidence of connection with an ice epoch had not been found.

If the Pensauken be the time equivalent of an early sheet of glacial drift, it constitutes, in its present condition, the strongest possible argument for the great lapse of time between this drift and that which is limited by the Belvidere-Perth Amboy moraine. The amount of erosion which it has suffered, as shown by its present distribution (Plate II) is very many times greater than that to which the last glacial drift has been subject, though the situation of the latter favors erosion as against the former.

South of the Raritan—Distribution.—In that part of Middlesex county which lies south of the Raritan, the Pensauken occurs in fine development in the vicinity of South Amboy, Ernston and Sayreville, in addition to areas heretofore referred to in earlier reports. South and east of these localities it occurs in isolated areas only. A glance at the accompanying map, and a comparison with the topographic map of the region, show that the relation between the distribution of the Pensauken and the topography of the region is intimate. It caps the isolated hills which rise above a certain level (80 to 100 feet), and it covers the ridges and the limited uplands at the same level. In short, it occupies the isolated crests, the divides, and the high level flats which have not yet been brought low, by stream erosion.

The level of its base in this region is often slightly, and locally notably, irregular. The normal level of its base may be said to be from 80 to 100 feet; but in the vicinity of Morgan station it declines to a level as low as 30 feet. In some other places, also, especially a mile and a half southwest of Ernston, the level of its base has much range, varying from an elevation of 35 feet to 100 feet or more within a short distance. Toward the Raritan river, too, its base occasionally runs down to 55 feet. The only other occurrences of Pensauken in the eastern part of Middlesex, not heretofore described, are small patches capping isolated hills, as near Morristown (west of Matawan)

and at a few points southeast of Browntown. It is wanting in the broad low tract about Keyport, and in the basin of South river, east of Old Bridge, and generally in the Mount Pleasant hills.

Thickness.—The Pensauken south of the Raritan, in the eastern part of Middlesex county, has a greater thickness than in most of the areas yet studied. The actual thickness is not usually shown by section, but where the formation occurs in a limited area only, the level of its base on either side of the prominence which it caps may be determined. Premising that its base is regular, and that the elevation above its base is composed wholly of this formation, its thickness can be calculated. On this basis, the formation is believed to be something like 70 feet thick in the vicinity of Sayreville, and 50 to 60 feet thick at some points in the village of South Amboy. From these figures its thickness ranges down nearly to zero.

Constitution.—In the vicinity of South Amboy and Ernston, the Pensauken is composed largely of coarse sand, made up of grains $\frac{1}{8}$ to $\frac{1}{31}$ of an inch in diameter. These are chiefly of quartz, and often well rounded. The grains of sand are very commonly coated with a light-colored substance, which somewhat resembles kaolin. This material, mixed with the sand, gives it something of compactness, so that it frequently stands with a more or less vertical face, and its exposed surface is likely to harden to some slight extent. The sand contains many tiny bits of distinctly recognizable granite, but they are uniformly so soft that they crumble on the slightest provocation.

With the coarse sand there is more or less gravel. This occurs in pockets, or veins, or layers. There is often a bed of gravel a few inches to a few feet in thickness at the base of the formation, and this gravel stratum often contains bowlders. These are occasionally as much as two or three feet in diameter. Among these stony masses there are often slabs of Triassic sandstone and shale, and occasional bowlders of crystalline rock of the gneissic or granitic type. Aside from these materials, the coarse constituents are quartz, quartzite and sandstone. The sandstone is sometimes, but not always, compact, and light colored. The quartzite is usually in the form of pebbles or cobbles, and appears to have come from various sources. Some of it is such as might have come from the Green Pond Mountain formation. Quartz is, on the whole, the most important of the several constituents of the gravel, and the pebbles are usually well rounded, resembling the gravel of the Beacon Hill formation.

In the vicinity of South Amboy the uppermost member of the formation appears likewise to have been gravel. This is shown by the fact that gravel remnants cap the finer material at a number of points in the vicinity. Thus in the 147 foot hill at South Amboy, where the material is well exposed, there is a gravel and bowlder horizon at the base, beneath a very considerable thickness of coarse arkose sand, and this latter is capped again by a thin stratum of gravel. The same thing is shown at some points about Ernston and Sayreville. In the upper gravel, the Triassic shale and sandstone, and the granite are wanting. It is uncertain whether this is because these materials were never there, or because they have weathered to such an extent as to lose their identity.

IN NORTHEASTERN MONMOUTH COUNTY.

In the belt of highland, running from the Navesink highlands on the northeast to Freehold on the southwest, there is little of the Pensauken formation remaining in its original position, for while it occurs at numerous places, its aggregate area is small. The situations in which it occurs fall into two groups. These are 1° isolated hill tops (not the highest), and 2° the slopes of high elevations which reached above the waters which deposited it. On the isolated hills, its height ranges from 60 feet or so, to 140 feet, or in some places even higher. In general it is to be noted that the remnants occur at higher and higher elevations with increasing distance from the seashore, or from main drainage lines. Thus, at Morristown (Middlesex county), the Pensauken occurs at an elevation of 120 to 130 feet, while near Browntown, three miles further southwest, the remnants occur at an elevation of 150 feet. In the vicinity of Englishtown, nearer a main drainage line, its elevation is again lower, ranging down to 110 feet. North of the railway, between Middletown and Hazlet, the base of the formation has an elevation ranging from 50 to 100 feet, and further north and northeast, in the direction of New Monmouth, it sinks as low as 40 feet.

In the second class of situations, in which the formation occurs, it forms benches on the slopes of the Cretaceous hills, or constitutes patches without marked topographic expression, on the slopes of the higher elevations. This may be seen about some of the Mount Pleasant hills, where the elevation is diagrammatically expressed by the following figure (Fig. 1).

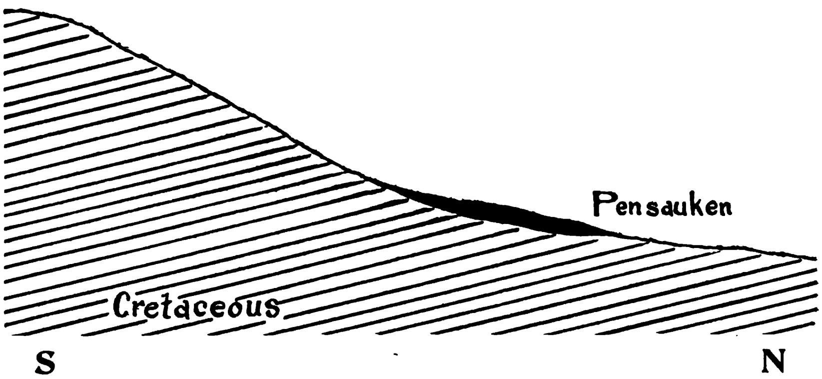

Fig. 1. Diagram Showing a Common Relation of the Pensauken to the Cretaceous in the Mount Pleasant Hills.

These patches occur especially on the north slopes of the hills, between Hazlet and Middletown. Along the upper courses of Willow brook and Crawford's brook, on the south side of the Mount Pleasant range, there are gravels ranging up to elevations of more than 200 feet. At first thought these gravels seem capable of reference to the Pensauken. But on the whole they seem to find their best interpretation as river gravels, accumulated perhaps through a long interval of time, the later portion of which was very recent. The constitution and the relation of these gravels, as well as their position, favor this interpretation. This interpretation, however, does not seem to apply to the gravels regarded as Pensauken on the north side of the Mount Pleasant Hills. Here, too, the constitution of the gravel negatives this conclusion, for at some points they contain material which does not appear to be of local origin. These patches on the gentler slopes along the northern side of the higher elevations between Hazlet and Middletown may perhaps represent the upper limit of the Pensauken waters.

South of the Mount Pleasant range there are remnants of gravel on various divides and isolated crests, which are probably to be correlated with the Pensauken. Thus along the crests south of Poricy brook there are remnants of gravel at elevations varying from 95 to 120 feet. The isolated patches are serially arranged and rise to the northwest. Again, on the crest between Nut Swamp brook and Swimming river, there are similar gravel remnants, ranging in elevation from 70 feet on the southeast to 100 feet on the northwest.

These remnants also are arranged more or less serially and rise up stream. There is a third row of gravel patches on the summits east of Hop brook, running from a point two miles west of Leedsville to the latitude of Morrisville. Similar remnants of gravel in similar topographic situations occur on the northwest side of the brook north of Holmdel. These remnants occur at elevations ranging from 90 feet on the southeast to 178 on the northwest. As in the other cases the existing gravel patches are serially arranged and cap the crests of the divides. In all cases the material seems to be of local origin. The granite, shales, etc., which characterize the Pensauken further north do not appear. The gravels here are chiefly of quartz and bits of water-worn ironstone, derived from the Cretaeous or the Miocene.

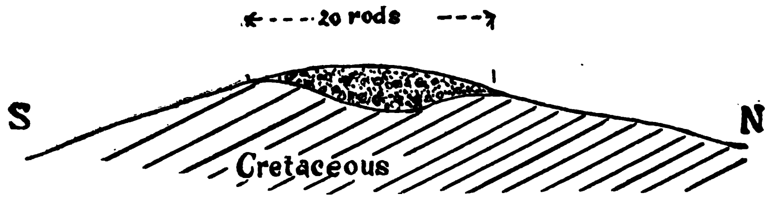

Fig. 2. Diagram Showing a Common Position of Remnants of the Pensauken Formation. Base Irregular.

Some of these patches of gravel have irregular bases (Fig. 2.), showing that the surface on which they were deposited was not even. The higher of these patches of gravel may be river gravel, the exact age of which is difficult of determination. But they appear to be connected in origin with the lower patches which represent the submarine portion of the Pensauken. The higher patches may have been deposited along valleys which were in existence at the time of the submergence which gave rise to the Pensauken formation elsewhere. In this event they would be Pensauken in age, but accumulated on the land, while the Pensauken in general was accumulating in the sea.

No Pensauken remains in its original position on Rumson Neck, and it is wanting throughout the basin of the Swimming river, excepting in three small patches near Branchburg and Deal. Its base here is forty to fifty-five feet above the sea. If it once existed in this region as a continuous sheet, as no doubt it did, it has been carried away by erosion.

Constitution.—About South Amboy, Ernston and Old Bridge, the Pensauken formation contains much granite, shale, and arkose sand,

but south of Cheesequake creek and Tennent's brook there is neither granite nor shale, and only occasionally is the sand arkose. In general, the coarser part of the formation is here made up of gravel which is of local origin, and which appears to have come from the destruction of the Beacon Hill and Cretaceous beds.

In places between Englishtown and Wickatunk, near the divide between Willow Brook and Milford Brook, and near the head-waters of the latter stream, there is a superficial formation over the Cretaceous, which is probably to be correlated with the Pensauken. It differs from the normal phase of this formation, in that it is more or less marly.

IN THE SOUTHWESTERN PART OF THE STATE.

The Pensauken formation in this part of the State was described in the last Annual Report. The work of the past season has been east of the area which had been studied heretofore, but the character of the formation, in the area newly surveyed, does not differ from that in the area which had been previously studied, and will not be described in this place.

CORRELATION.

In the Annual Report for 1895,* the question was raised as to whether the Pensauken, as there defined, did not really consist of two distinct formations. To this question the work of the present season seems to point to an affirmative answer, and to connect the older (and topographically higher) division with the Beacon Hill formation. The sections published in the Annual Report for 1895 illustrate the topographic relations of the two divisions of the Pensauken, as they were then called, in the southwestern part of the State. The relations are more fully illustrated by the sections (Plate III) accompanying this report, and the topographic discrepancy between the two divisions is more marked in the central part of the State than to the southwest. The interpretation which now seems most likely to prove true is shown on the accompanying map (Plate II).

The sections (Plate III) show that the base of the Beacon Hill formation declines notably to the southeast in the direction of dip, and some of the sections show that its base is notably uneven along the line of

*Ann. Rep. p. 12.

strike, being highest in the Beacon Hill region, and lower both to the northeast and to the southwest.

It now appears that the base of the Beacon Hill formation as earlier defined, with its notable dip to the south, corresponds with the base of the higher division of the formation previously called Pensauken. This correspondence is the principal reason for believing that they are one, though they are also similar in constitution. So strong is this similarity that when the upper division was regarded as Pensauken, it was believed that it must have come principally from the Beacon Hill formation.

It appears that the Pensauken proper, like all other formations of South Jersey, declines to the southward, and that, in the extreme southern portion of the State, it will be found to be confined to very low levels; but its relation to the older division of the Pensauken (the probable Beacon Hill) in southeastern New Jersey, is yet to be determined.

THE PENSAUKEN FORMATION IN THE VICINITY OF PHILADELPHIA.*

A few words are here added concerning the Pensauken formation on the west side of the Delaware in the vicinity of Philadelphia. The formation here is somewhat sharply limited above, at an elevation of 120 to 130 feet. It extends from the Delaware river back to this elevation, but fails to rise above it. This limit is found west of Germantown Junction, in the western part of Philadelphia. Along the western edge of the region where it occurs, the base of the Pensauken has an elevation of 100 to 120 feet. Eastward from its western limit, the base of the formation declines until it reaches a level which is quite down to tide level, and sometimes below it, in the immediate vicinity of the Delaware. In the immediate vicinity of the Schuylkill its base is often 30 or 40 feet above tide.

The upper surface of the Pensauken does not decline to the eastward in anything like the same ratio that its base does. It follows that where it has not been notably eroded, the formation is much thicker toward the Delaware than near its western limit. In the western part of its area it reaches thicknesses of ten, and occasionally of twenty or thirty feet. Toward the Delaware, its thickness often

*These statements are based on work done for the U. S. Geological Survey, and are published with the consent of the Director.

exceeds these figures. Thicknesses of thirty or forty feet are not unusual, and even these thicknesses do not reach or even approximate the original thickness of the formation.

The elevation of the base of the formation at Haddonfield, N. J., is from 100 to 120 feet, approximately the same as the level of the base of the formation in the vicinity of Haddington. It is probable that the area between these two localities was originally filled up with the Pensauken material so that its surface was approximately level. If this be true, fully sixty feet of the Pensauken formation must have been removed by erosion, in the vicinity of the City Hall in Philadelphia. In this vicinity the formation has now a thickness of something like 40 feet, so that its original thickness, calculated as above, must have been as much as 100 feet.

There is abundant evidence that the Pensauken was deposited on an uneven surface, some parts of which were below the present sea level, and some of which were considerably above it.

Constitution.—The Pensauken material in the vicinity of Philadelphia is, in a general way, like that on the New Jersey side of the river, but differs from it in that its coarse material is more angular, less well assorted, contains a larger proportion of local gneissic material, and in general a larger proportion of material such as might have come down the Schuylkill drainage line; while that on the New Jersey side of the river above Philadelphia seems to be made up of materials which, to a greater extent, may be supposed to have come down the Delaware.

THE BEACON HILL FORMATION AND THE MIOCENE.

The relation of the Beacon Hill formation to the Miocene is difficult of definition, and seems likely to remain debatable. From the top of the Beacon Hill formation down to the Cretaceous the generalized section is as follows, commencing with the top:

1—Gravel, principally of quartz and chert.

2—Coarse sand, with occasional small pebbles.

3—Very fine, fluffy sand.

4—Clay.

The third and fourth members of the foregoing series have constantly been regarded as Miocene, and no adequate ground for separating these two members from the two above has been found. It is because no adequate ground of separation has been found, and because the two lower members have been thought to be Miocene, that the whole of the Beacon Hill formation has been tentatively referred heretofore to that formation.

The beds which have heretofore been regarded as distinctively embraced under the name Beacon Hill have been the first and second of those mentioned above. The question has frequently been in mind whether the gravel of the Beacon Hill formation (No. 1, above) and the coarse sand which lies just beneath it (No. 2, above) are really one or whether they represent two distinct formations. The former of these alternatives has been steadily regarded as the more probable. There are not wanting phenomena, however, which suggest that the division between the Beacon Hill and the Miocene, if such a division has to be made at all, is to be placed above the coarse sand rather than below it. Dr. Clark's work on the Miocene will doubtless help to settle this question.

The general facts concerning the distribution of the Beacon Hill formation have already been published. Aside from capping Beacon hill, Telegraph hill and one or two other hills in the same range, it is found in the Navesink highlands, at several points in the vicinity of Chapel hill, at two points just east of Red Bank, on three of the most conspicuous elevations between Yellow brook and Hop brook a few miles southeast of Red Bank, on some of the elevations two or three miles northeast of Freehold, and on the high hill near Oakland Mills. Aside from these small isolated areas, it forms a nearly continuous stratum to the southward, commencing with the line of highlands between Asbury Park and Colt's Neck. It also covers most of the area south of the Manasquan river.

Of the several beds enumerated above, the gravel has a variable thickness, and what now exists is probably no more than a remnant of the original bed. Since it lies at the top it has suffered much erosion and now rarely reaches a thickness of ten feet. The coarse sand often varies from 10 to 30 feet in thickness, and locally, especially in the Hominy hills, is much thicker. The fine sand which lies next beneath the coarse is often something like 30 feet in thickness, and for the clay below it and into which it grades by interlamination, 10 feet is a common thickness.

The clay does not appear in Beacon Hill nor in the other hills of the Mount Pleasant range, though the fine sand does.* In the Navesink highlands there is some clay interlaminated with fine sand, though it is not known that any considerable bed of it exists.

The clay bed does not appear to extend so far to the northwest as the other members of the series. Indeed, it is not traced as a distinct bed north or northwest of the Hominy hills. It is well exposed at Ludlow's pits just west of Asbury Park. The same stratum is seen again in the railway cut one and a half miles north of Shark River station, and at several points about the northern base of the Hominy hills.

POST-PENSAUKEN SUBMERGENCE.

About the Head of Raritan Bay and in Northern Monmouth County.—Evidence of any considerable submergence in the last glacial or post-glacial time or, indeed, in post-Pensauken time, is not abundant in the vicinity of Raritan river and bay. At various points there seems to be decisive evidence of submergence up to a level of 40 feet or so, within recent (last glacial or later) time. This is shown both along the Raritan river and further south and east in the vicinity of Morgan Station, Matawan, Keyport and the Navesink highlands. About South Amboy, there are phenomena up to heights of 130 feet, which seem best explained on the basis of late (post-Pensauken) submergence, but the evidence is not abundant.

In the vicinity of Red Bank there is abundant evidence that the land has recently been about 40 feet lower than now. This is shown by the terrace-like flats at this elevation along the coast and up the streams. For some distance up the larger streams, such as Swimming river, there are terraces corresponding in elevation with the terraces along the coast. Still further up the streams, however, there are terraces which, while not corresponding in elevation with those of the coast, rise gradually from them to the heads of the streams. Their relations are such as to indictate that they are to be correlated in time

*The existence of the fine sand here was not known when the name of this hill was given to the formation.

with the 40-foot terraces around the coast. These terraces rise to a maximum of more than 200 feet near the head waters of the drainage lines which work back into the Mount Pleasant hills. They have their highest elevation along a branch of Hop brook, near Crawford's Corner. These terraces are believed to have been developed by normal stream action, the process, perhaps, coming down to the time of the lower terraces along the coast, and in the lower courses of the rivers.

In the southwestern part of the State.—Along the lower course of the Delaware likewise, the evidence of post-Pensauken submergence is meagre, or fails altogether, at high altitudes. In the vicinity of Wenonah such evidence is found up to levels of 70 feet; in the vicinity of Swedesboro, up to 50 feet; and in the vicinity of Salem, not above 25 or 40 feet. It is possible that greater submergences may have occurred without leaving indubitable records. This is made the more probable by the fact that the Philadelphia brick clays, running up to levels of 150 or 160 feet, are to be correlated with the loams and clays at lower levels on the opposite side of the Delaware.

The Philadelphia Brick Clays.—The Philadelphia brick clay mantles most of the Pensauken formation of the vicinity, and rises on the crystalline schists 30 to 40 feet higher. In some places on the west side of the Schuylkill this clay or loam is traceable, in continuous development, from levels of 60 feet to levels of 140 or 150 feet. Of the continuity of the mantle there seems to be no doubt, and this continuity is the best evidence of its contemporaneity throughout. East of the Schuylkill, and between that stream and the Delaware, the same continuity of development is seen wherever exposures, can be found. Here it commonly overlies the Pensauken formation, but it sometimes rests on the gneiss, where the Pensauken has been removed from it. The same loam is found overlying the Trenton sands and gravels in the lowlands next to the Delaware. This was seen at Front and Bainbridge streets, Philadelphia, as well as at several other points in the northern part of the city.

This brick-clay or surface loam varies in thickness from one to twelve feet. Its greatest known thickness is found just east of the Schuylkill valley below Gray's Ferry. It is here dug as brick-clay, and has a depth of 12 feet, 40 feet above tide. It here occurs in the great valley which the Schuylkill had excavated out of the Pensauken in post-Pensauken time. The loam or clay attains nearly as great thickness in the vicinity of Haddington, at 59th street and

Haverford avenue, at an elevation of 100 feet. It here overlies the Pensauken, where the latter had suffered little erosion before the deposition of the former. Thicknesses of as much as ten or twelve feet are the exception rather than the rule.

The loam seems to be distinctly unconformable on the Pensauken. This is shown at many points, and especially by the fact that it lies on gneiss or schist surfaces from which the Pensauken had been removed. It is further emphasized by the fact that it mantles deposits of gravel of last glacial age made in the bottom of the Delaware valley after the latter had been excavated to a depth of nearly 100 feet in the Pensauken formation.

The deposit varies from a sandy loam to a heavy clay-loam. There is no very evident relationship between its character or its thickness, and its topographic position.

ROAD MATERIAL.

NORTHERN MONMOUTH COUNTY.

The northern part of Monmouth county, including the townships of Matawan, Raritan, Holmdel, Middletown, Shrewsbury, Eatontown, Atlantic, Marlboro, and parts of Manalapan, Freehold and Howell, has been studied in such detail that it is possible to make some general suggestions concerning the available supply of road material. Throughout this region, the available road material is not abundant, but gravel in small quantities is somewhat widely distributed. The areas where it occurs are shown on the accompanying map (Plate V), where the areas are somewhat exaggerated in size. In many of these places pits have already been opened and the materal utilized. It is safe to say that pits have been opened in most of the areas where the road material is of high grade, but in some of these situations the supply is large enough to furnish the necessary material for many roads which have not yet been improved.

In many places the available road material consists of remnants of the Pensauken formation* which caps some of the isolated hills

*It will be remembered that reference was made in the Annual Report for 1894 to the fact that the Pensauken formation, as a whole, is capable of contributing much to the available road material of the State

and ridges of the region. In other places, as along the range of hills extending from Chapel hill to Wickatunk, there is more or less semi-indurated marl at the surface, which, as a rule, not only constitutes a good road-bed where it occurs, but has become a local source of supply of material for roads less fortunately situated.

No estimate has been made of the total amount of the road material of northern Monmouth county, but the total supply is not great, probably not great enough for the needs of the region. There is enough, however, to allow of great improvement in the roads as a whole, for while there are already many good roads in this part of the county, it is still true that there are many others in urgent need of improvement.

It is unfortunately true that the gravel is not all of the best grade, though much of it is good, and some of it, like that near Shark river, is of a very superior quality. By proper management, much of the material which at first sight seems ill-adapted to road purposes may be used to good advantage. This is especially true of the gravels which are too lose (too little matrix) for the best results. An admixture of fine material of such a nature as to cause them to pack, is sometimes practicable.

It should be stated that various parts of the region covered by the map vary greatly in their needs. In some districts the soil is sandy, and the road-beds remain poor, except where they have been carefully attended to. This is true of the belt embracing the following tracts: The northern and western portions of Manalapan township, the northern portion of Freehold, the western half of Marlboro, the extreme northern portion of Holmdel, Raritan, and the northern portion Middletown. The matter of roads in this region is especially important, since much of the land, though sandy, is well adapted to truck farming. Much of it is now used for this purpose, but some of it would have its value enhanced if the roads were so improved that the products could be more easily marketed. Throughout this belt there is more or less road material, but it is not equal to the needs of the region, nor is its quality so good as could be desired, but there is much material in this belt which has not been utilized, which would, at least, greatly improve the roads.

In other districts, good road-beds are secured by simply grading the natural surface without the addition of any foreign material what-

soever. This is true of much of the region along the range of hills running from Chapel hill to Wickatunk. The good road-beds throughout much of this region are due to the indurated marly sand which forms the crest of many of the ridges on which the roads run. This material not only forms a good road-bed where it occurs, but is, to some slight extent, available for use elsewhere.

In the gravel the largest constituent is quartz pebbles. Much of it, however, contains bits of ironstone, which crush under the wheels, and furnish a binding material for the pebbles. In other cases there is some soft chert which serves the same purpose as the iron. A little clay or loam is sometimes present, which likewise helps to bind the gravel into a solid mass in the road-bed. In some places there is iron-stone conglomerate in such quantities as to make the gravel difficult to work, but even this conglomerate, when not so hard but that it may be broken up, furnishes an excellent material for the road-bed.

WESTERN CAMDEN, GLOUCESTER, SALEM AND CUMBERLAND COUNTIES.

In the Annual Report for 1894 * reference was made to the road material of the southwestern part of the State, so far as it had then been studied. What was then said had reference especially to southern Mercer, northwestern Burlington and the western part of Monmouth counties. Mention was also made of certain other localities in regions which had been reconnoitered, where gravel well adapted to road purposes occurs. The area of detailed study has now been extended, and the maps (Plates VI, VII,) show in a general way the distribution of the road materials in the area which has been studied since the annual report for 1894 was issued. The gravel is already utilized to a large extent, a fact to which the many good roads of the region bear significant testimony.

It is not to be understood that the whole of all the areas represented on the map is covered with good road material, but that within these areas good road material is likely to be found at almost any point, and that it has actually been found and developed at many points. The thickness of the gravel is such—often five to ten feet—that in view of the great area which it covers, the amount is entirely adequate to the needs of the region, although it is not so well dis-

* Pp. 133 to 142.

tributed as could have been desired. A somewhat extensive belt next the Delaware is essentially without road gravel.

The variations in the quality of the gravel are due to (1) the variable amount of loam, clay, etc., which serves as a matrix; and (2) the variable amount of soft material, such as soft cherts, bits of ironstone, etc., which crush under the wheels and so help the gravel to pack in the road-bed. Where both these elements which help the gravel to pack fail, and the matrix of the gravel is sand only, it is too loose for good results, unless mixed with materials which supply the deficiency. Within the area shown on the map, however, there is much gravel ready for the road-bed as it is taken from the pit. This has been most developed in the vicinity of the more prosperous cities and villages.

The suggestion made in an earlier report is here repeated, that much gravel which taken alone is not of the first quality, furnishes a good road-bed when properly mixed with other materials which supply its deficiencies. When such materials occur near each other, as is often the case, they may frequently be combined advantageously without great cost or inconvenience.

EXPLANATION OF PLATES.

Plate I.

Map showing progress of detailed work on the surface formations of the State.

Plate II.

Map showing the distribution of the Pensauken formation, so far as now known, and the gravel (upper member) of the Beacon Hill formation, so far as it has yet been studied. (See page 11.)

Plate III.

A series of sections drawn from northwest to southeast, essentially at right angles to the strike of the beds. They are designed to show especially the stratigraphic and topographic relations of the Pensauken and Beacon Hill formations.

Section 1 extends from Bordentown to Taylor's Mount (near New Egypt) and beyond. The topographic discrepancy between the Pensauken and Beacon Hill formations is here less distinct than in the other sections. It will be seen that near Bordentown and Chesterfield the base of the Pensauken has an elevation of less than 100 feet. Southeast of Chesterfield it has an elevation of about 120 feet. Its base therefore rises slightly to the southeast. At Jacobstown, the base of the Beacon Hill has an elevation of about 150 feet, and at Taylor's Mount an elevation of about 120 feet. Thus the Beacon Hill formation is seen to decline to the southeast. Carried to the northwest, the base of the Beacon Hill, near Chesterfield, if it were continued with the same dip, should lie at an elevation of 200 feet, whereas the base of the Pensauken is very much lower.

Section 2 represents a section from a point northwest of Clarksville through Newtown, Allentown to Prospertown and beyond. Near Clarksville the base of the Pensauken has an elevation of about 90 feet. Between Clarksville and Newtown the elevation of the base is slightly less. At Newtown its base reaches a maximum elevation of about 120 feet. Near Davis Station its elevation is about the same. Two miles southeast of Davis Station the Beacon Hill formation appears, and its base has an altitude of 195 feet. Southeast from this

point its base declines, and four miles to the southeast is at an altitude of about 160 feet. If the angle of slope here indicated be carried to the northwest, the base of the Beacon Hill at Newtown, if it existed there, should be 275 to 300 feet above sea level, whereas the Pensauken is only 120 feet.

Section 3 is a section essentially parallel to the preceding, extending from Sand Hills near Bonhamtown through Beacon hill, Sugar Loaf (or Polhemus) hill to the Hominy hills. At the north end of this section, it will be seen that the base of the Pensauken has an elevation of about 100 feet, at South Amboy 90 to 100 feet, and at Morristown about 120 feet. The Beacon Hill formation is first shown in this section at Beacon hill, where its base has an elevation of about 360 feet. It appears again on Sugar Loaf hill, where its base has an elevation of about 160 feet, while in the Hominy hills its base has declined to a little over 90 feet. With the slope indicated by the elevation of the base at these three localities, the Beacon Hill formation, if extended to the northwestward, should have, in the vicinity of South Amboy, an elevation of between 500 and 600 feet.

Plate IV.

This plate represents sections essentially parallel to the strike, and therefore nearly at right angles to the preceding sections, extending from Salem on the southwest to Pine hill, near Perrineville and Clarksburg, on the northeast. The three sections presented are continuous, and follow each other from southwest to northeast. Along this line of strike it will be seen that the Beacon Hill gravels are first seen in unmistakable development near Harrisonville where its base has an elevation of about 120 feet. At Jefferson the base of the formation is 130 feet. At Barnsborough it is slightly lower. At Marlton hill about 150 feet. In section IVc. of this plate, the Miocene formation and the Beacon Hill gravel are not separated from each other. The base of the Miocene in Arney's mount has an elevation of about 100 feet; at Sykesville its elevation is about 150 feet; at Ellisdale about 210 feet; at Imlaystown about the same, and east of point its base is somewhat higher, ranging between 240 and 270 feet. It will be seen, therefore, that the base of the Beacon Hill and the Miocene decline notably, and together, to the southwest along the line of strike.

If these sections be compared with those published in the Annual Report for 1895, further light will be thrown on the relations. It is explained, however, in the body of this report (p. 11), that some of the material classed as Pensauken in the sections published in 1895, is now regarded as belonging to the Beacon Hill formation.

Plate V.

Map showing the distribution of road material in northern Monmouth county.

Plate VI.

Map showing distribution of road gravels in western Burlington, Camden and Gloucester counties.

Plate VII.

Area showing distribution of road gravels in western Salem and Cumberland counties.

THE

PART II.

THE NEWARK SYSTEM.

REPORT OF PROGRESS

BY

HENRY B. KÜMMEL, Ph.D.

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OUTLINE.

INTRODUCTION.

During the past season I was in the field from the seventh of April until the tenth of September. With the exception of the latter half of the month of June, when I was engaged on the United States Geological Survey, my time was spent in detailed work upon the

Newark system, in the western part of the State. The investigation, of which the following is a report of progress, was commenced in the latter part of 1895, and several weeks were spent in the field, chiefly in reconnaissance work. Although this preliminary work was, to a great extent, barren of decisive conclusions, it was of value in suggesting lines along which the solution of mooted questions was to be sought. It was soon recognized that the only hope of making out the structure of the beds, their subdivisions and thickness, and of locating faults, lay in detailed examination and plotting of all the outcrops. In carrying out this plan, practically all the roads have been traversed, the sections along nearly all streams examined, and the dip of the beds carefully observed and plotted on large scale maps. At the same time notes were made of the color and lithological character of the beds. This method of work, of necessity, has been slow, but the results obtained have justified the expenditure of time. In preparing this report I have endeavored to avoid technical terms, or, where used, to explain them. To make the report of interest to people without special training in geology, it has been necessary to write more in detail than would be the case were it prepared for geologists only. In this connection I desire to express my thanks to Dr. C. M. Larison, of Ringoes, to whom I am indebted for aid in locating several small trap dikes in that vicinity.

Nomenclature.—Following the usage established by the United States Geological Survey, the term "Newark System" has been adopted in this report. The rocks which are included under this term have been called by various names. Russell* gives a list of over twenty different names applied to these and similar rocks in other States.

In the reports of the State Geologist of New Jersey, the term Triassic or Red Sandstone has been most commonly used. The term Newark was proposed by W. C. Redfield† in 1856. It is the oldest specific title which makes no implication as to the geologic age. It has been impossible to determine satisfactorily the precise position of these rocks in the geological column based upon the European systems. It is, therefore, better to use a name which does not imply a correlation in time, which may or may not be correct.

* I. C. Russell, Bulletin of the U. S. G. S., No. 85, pp. 16–18.

† Am. Jour. Sci., 2d Series, Vol. XXII, 1856, p. 357; also in Am. Assoc. Adv. Sci., Proc., Vol. X, Albany meeting, 1856, p. 181.

GEOGRAPHY.

General Area.—The Newark System extends across the northern part of the State, forming a belt which is about thirty-two miles wide along the Delaware river, extending from Trenton to within two miles of Riegelsville, while its width at the New York State line is about fifteen miles. The southeastern boundary extends from Trenton to near the mouth of Lawrence brook, below New Brunswick, thence to the Arthur Kill, three miles northeast of Woodbridge. From this point the boundary in general follows the waters of the Kill von Kull, New York bay and Hudson river. For the greater part of the distance from Woodbridge to Trenton, the Cretaceous adjoins the Newark rocks and partially conceals the lower beds. The northwestern boundary begins at the Delaware at Holland, below Riegelsville, and passes near Pattenburg, Jutland, Clinton, Allerville, Lebanon, Apgar's Corner, Pottersville, Peapack and Bedminster. From Bedminster it extends in a nearly straight line to Suffern, N. Y., passing near Bernardsville, Morristown, Boonton and Pompton. The rocks along this border are all much older than the Newark sandstones. The formation extends northeastward into New York, and southwestward into Pennsylvania.

That part of it lying southwest of a line drawn from Metuchen through Plainfield to Peapack has been studied in detail, and it is with this part principally that this report has to do. Parts of Mercer, Somerset, Middlesex, Hunterdon and Morris counties are included in this region.

The Topography.—In its general features the topography is simple. It consists of a gently rolling plain, having an average elevation of between 100 and 250 feet, A. T. Considered as a whole, it is lowest along the southeastern margin, and rises to the north and northwest, the most marked exception being found in the region between New Brunswick, Bound Brook and Somerville. Here the descent is to the northwest, from an average elevation of about 130 feet, A. T., around New Brunswick to about 70 or 80 feet about Bound Brook. The plain is well developed north and west of New Brunswick, although somewhat dissected by narrow gullies near the Raritan river. It is also well shown along the line of the Philadelphia and Reading railroad between Bound Brook and Skillman. Between Pennington and

Lawrenceville, south and east of Flemington, and south of White House it is well developed.

This plain is more or less interrupted and its continuity destroyed by valleys, which have been sunk below the general level, and by hills, ridges and plateaus of harder rock which rise above it. The latter are more important as topographic features than the former and will be mentioned first.

Hunterdon Plateau.—Commencing at Raven Rock on the Delaware river, a prominent escarpment extends northeastward, past Sand Brook and Flemington, where it bends to the north and then to the northwest, finally terminating near Lansdowne, about eighteen miles from the Delaware river. North and west of this line is a broad plateau, in places extremely flat and poorly drained, having an average elevation of about 600 feet. North of Cherryville it rises to a maximum height of 706 feet. It extends westward into Pennsylvania, and is dissected to a depth of from 400 to 500 feet by the Delaware river. Locally, this plateau is known as "the Swamp," from the fact that before it was cleared and drained much of it was wet land. Its streams, obstructed on the level surface by vegetation, lacked the fall necessary to drain it properly. Even to this day much of the soil is heavy and cold.

The highest part of the plateau is along the south and east, about a mile back from the top of the escarpment. Thence it declines in elevation very gently northward and westward. Along its margin and near the Delaware river the plateau is cut by deep, narrow gorges, whose bottoms ascend rapidly, and rarely extend back into the plateau more than three or four miles. The upper courses of the streams lie in broad, shallow valleys, but slightly depressed below the general level of the plateau. The escarpment on the south and east is most sharply marked in the vicinity of Flemington, where the general elevation of the country at its foot is 200 feet or less, and at its top about 550 feet. To the southwest, in the vicinity of Sergeantsville and thence to the Delaware river, the contrast is not so marked, owing to the greater elevation (340–450) of the country at the foot of the escarpment. As will be shown later, this fact finds a ready explanation in the geological structure.

Gravel Hill and the Barrens.—At intervals along the northwestern boundary there occur thick beds of heavy conglomerate, forming hills which rise 300 to 400 feet above their surroundings.

The most conspicuous of these are Gravel hill, northwest of Milford, elevation 865 A. T., and the line of hills south of Pattenburg, known as "the Barrens," 800 to 900 feet A. T. From the crests of these hills the surface descends rapidly to an elevation of about 450 feet, the height of the northern and lower margin of the Hunterdon plateau, which adjoins the conglomerate hills on the south.

Sourland Mountain.—This plateau—for it is more a plateau than a mountain—rises from the Raritan valley near Neshanic, attaining its maximum elevation of 563 feet two and a half miles south of that village, and extends southwest to near Lambertville on the Delaware, seventeen miles distant. Here it has an elevation of 457 feet. The backbone of the plateau is trap-rock, which forms a belt about a mile in width, but the hard sandstones, shales and argillites on either side rise nearly to the same elevation as the trap, and form a plateau having an average width of about four and a half miles. For six miles from the Delaware along the southeast border, Belle mountain, 303 feet; Bald Pate mountain, 482 feet; Mount Canoe, 480 feet, and Pennington mountain, 460 feet, irregular shaped masses of trap-rock, increase the width of high ground to nearly six miles. They are separated from the Sourland plateau and from each other by narrow valleys. Northeast from these hills the escarpment of the plateau rises somewhat steeply above the red shale plain to the east and southeast, having a height of over 200 feet near Hopewell, and over 400 feet further north. To travelers on the Philadelphia and Reading railroad between Hopewell and Bound Brook this steep slope is the most conspicuous feature of the landscape. The descent from the plateau on the northwest to the low plain about Flemington is too gradual to be called an escarpment.

Rocky Hill.—This trap ridge commences near Hopewell and extends eastward for fifteen miles or more before it finally disappears. Near its western end its width is hardly more than a quarter of a mile, with a maximum elevation near Mount Rose village of 415 feet—about 200 feet above the sandstone plain on either side. Eastward its width increases to over a mile at Rocky Hill village, where it is cut through by the Millstone river in a narrow gorge. Its height, however, is declining, and near Monmouth Junction it merges into the general level of the plain. A spur, which projects northward from the main ridge just east of Rocky Hill village, extends to Griggstown and thence to Ten-Mile Run, where it also merges into the plain.

Cushetunk Mountain and Round Mountain.—The former is a curved ridge of hard trap-rock, south of Lebanon, having a maximum height of 839 feet. Its crest and inner slope has the exact shape of a horse-shoe, the toe pointing to the southeast. The distance across, between the heels, is about one and a half miles and the length is two and a half miles. The ridge is situated near the northwest boundary and the heels of the horse-shoe almost touch the crystalline hills, so that Round Valley, within the horse-shoe, is rightly named.

Round mountain, as its name indicates, is a dome-shaped hill which rises nearly 400 feet above the general plain. It is situated just south of Stanton, not far from the southern limb of Cushetunk mountain.

The Watchung Mountains.—The southern ends of the crescent-shaped Watchung ridges lie in the region which was studied in detail. These concentric parallel ridges are alike in both having steep, short southerly faces, gentle, long northern slopes, and remarkably even crest lines, which are occasionally broken by deep, narrow gorges. The southern or outer ridge has an average elevation of about 500 feet, whereas the inner ridge is in general from 50 to 125 feet higher.

The Hydrography.—The drainage of this region is through the Delaware and Raritan rivers and their tributaries, the drainage area of the latter being between four and five times as large as that of the former.

The Delaware and Tributaries.—The Delaware river in its course of thirty-eight miles across the Triassic area flows in a narrow trench, the depth of which varies considerably. Above Milford, bluffs rise on both sides of the river to a height of over 300 feet, the bottom of the trench being less than half a mile wide. Between Milford and Frenchtown, the bluffs are lower and not so steep, but for nine miles below the latter place, crossing the Hunterdon plateau, the river runs through a narrow gorge, which increases in depth from 200 feet at Frenchtown to 470 feet at Tumble. Below Raven Rock, where the plateau escarpment reaches the river, the sides of the trench are lower and less steep, but they rise again and regain their steepness at the narrow gorge which the river has cut through the Sourland plateau, below Lambertville. From Titusville to Trenton the trench is shallow, and its sides, although steep, are never vertical, as is the case where the bluffs are higher. At Trenton the river is at tide, whereas the average level of the country a mile back from the river is about 120 feet A. T. In

general the tributaries of the Delaware are short, swift streams in ravines or gorges, narrow and steep near their mouths and rising rapidly to the general level of the country. The larger ones have developed narrow flood-plains along their lower courses. In many cases, noticeably in those which drain the Hunterdon plateau, the upper part of the stream occupies a broad, shallow depression scarcely sunk beneath the surface of the plateau. From these upper reaches the streams descend by steep slopes, often tumbling over ledges in picturesque rapids and cascades to the quieter stretches near their mouths. The Lockatong and the Wickecheoke are the best examples of this phase of stream development.

The Raritan.—The two branches of the Raritan river, with its principal tributaries, the Millstone and the Neshanic, drain the greater part of the area under discussion. These streams, in general, lie across the low, rolling plain whose average elevation is, normally, between 100 and 200 feet A. T., and they, therefore, have had no opportunity to cut deep valleys. Near New Brunswick the Raritan valley is a narrow, steep-sided trench, about eighty feet deep. In the vicinity of Bound Brook and Somerville the general elevation is less and the trench is wider and shallower. The trench of the Millstone averages about seventy feet in depth, but at Rocky Hill, where it crosses the trap ridge, it is over two hundred feet deep. Locally, along Stony Brook and the Neshanic, there are bluffs eighty to one hundred feet high, but, in general, heights above the streams are less than this. The small side-tributaries, particularly those of the Raritan below Bound Brook, often enter the parent stream through narrow, steep-sided ravines, in many cases not more than a mile or two in length.

GEOLOGY.

It has been found possible to divide the sedimentary rocks of the Newark System into three subdivisions. These divisions are not based upon fossil evidence, but upon lithological differences, which imply diverse conditions of sedimentation, and which permit the establishment of recognizable horizons. Although the beds of each series *en masse* are quite unlike those of either of the others, there are in each some layers which resemble more or less closely beds in one or the other series. The three series are not separated from each other by sharply-marked division planes, but, on the contrary, grade into

each other vertically through transition zones which are several hundred feet in thickness, so that it is not always easy to delimit them exactly in the field. Moreover, it was found that all three members lost, to some extent, their distinctive characteristics when traced along the strike toward the northwest border, and that little reason could be found for there dividing the formation. But with these qualifications, it is true that the three divisions are distinct from each other. The accompanying map, plate VIII, shows the position of these subdivisions, and the main faults by which they are repeated.

Stockton Series.—The basal beds of the system are found at Trenton, where they rest upon the older crystalline rocks—the Philadelphia–Trenton gneiss belt. They consist of (*a*) coarse, more or less disintegrated arkose conglomerates; (*b*) yellow micaceous, feldspathic sandstone; (*c*) brown-red sandstones or freestones, and (*d*) soft red argillaceous shales. These are interbedded and many times repeated, a fact which indicates rapidly-changing and recurrent conditions of sedimentation. Although there are many layers of red shale in this division, the characteristic beds are the arkose conglomerates and sandstones, the latter of which afford valuable building-stones.

The conglomerates and yellow sandstones prevail near the bottom, and the brown-red sandstones near the top, but the lower beds are not all conglomerates, as is shown by the fact that the lowest beds exposed, very near the base of the series, are red shales, interbedded with conglomerates. Layers of soft, argillaceous, red shale are also found separating the brownstone beds near the top of the series. Occasionally, also, there are thin layers of green, purple and black shale, but they are inconspicuous.

The conglomerate beds are made up chiefly of quartz pebbles, often three or four inches in diameter, and fragments of feldspar crystals, occasionally measuring an inch or more across. As seen with the naked eye, the cleavage faces of these are generally but little affected by weathering. Some mica is present and a few pebbles of sandstone and slate occur. The yellow standstones are composed of essentially the same materials as the conglomerate but finer.

In addition to the quartz and feldspar, which are the chief constituents of the brown and grey freestones, there is some mica. Minute rust colored specks in the sandstone are probably due to some disintegrated ferro-magnesian minerals. It is not uncommon to find pebbles of various kinds sparsely scattered through the sandstones.

These are mostly quartz, but there are fragments of red shale, often somewhat irregular in shape, which seem more like masses of clay deposited with the sand and afterward hardened than water-worn pebbles of shale. Cross-bedding in the sandstone is quite common.

The shale is composed of fine red mud, containing more or less minute flakes of mica. In some cases it occurs in thick beds, which, when seen in a freshly-exposed wall in the quarry, appear firm and massive. However, it splits readily on exposure to the weather. Rarely, a thin bed of green or black shale occurs with the red.

This series of beds is best shown in the quarries near Wilburtha, five miles above Trenton, and also in the quarries near Stockton. Because of the fine exposures near the latter place this division has been called the "Stockton series." In all these quarries the rapid alternation of beds from shales to freestones and to arkose conglomerates is shown. Not infrequently a well-marked bed was seen to thin out rapidly within the limits of a quarry, or even disappear entirely, its place being taken by a layer of a different texture. In other cases the same bed, although retaining its identity as a distinct layer, yet changed so in texture or color along its plane that it would not be recognized as the same bed were it not visible through all this distance. The individual beds have the shape of thin lenses, which overlap at their edges where they thin out.

In addition to the cross-bedded structure which often prevails in the sandstones, ripple-marks, mud-cracks and impressions of rain-drops have been observed on the shale layers. The conditions under which these beds were deposited will be discussed in a final report, but it may be said in passing that there is every indication that they were formed in the shallow water, in close proximity to the shore, after the manner of the seashore deposits of the present day. The bulk of the material of which they are composed was derived from the crystalline rocks on the south and southeast.

Distribution--Trenton-Wilburtha Area.—As shown upon the map accompanying this report, there are four areas occupied by the Stockton series. This is due to the faulting and folding which the whole formation has experienced. These areas are as follows:

The first belt begins in the western part of Trenton and extends along the Delaware to a point about three-fourths of a mile above Wilburtha station. At Trenton the formation rests upon very much older crystalline rocks, which have contributed largely to the arkose

beds. But it is only for a short distance that the basal beds are exposed, because a few miles northeast of Trenton, the Cretaceous clays overlap and conceal the lower part of the Stockton series. The upper limit of this division extends from the Delaware river above Wilburtha, through Ewingville, Lawrence and Princeton. At the latter place it crosses the college campus, and excavations made for the foundations of the new college library revealed the upper beds of this series. Along the Millstone river the line of separation between the Stockton series and the overlying beds can be quite accurately located in the line of quarries along the canal, the southern quarries being in the Stockton series. East of the Millstone river the boundary line cannot be determined, owing to thick deposits of the Pensauken which mantle the surface of this region. Northwest of Trenton this belt has a width of about three miles, but to the northeastward, owing to the overlapping of the Cretaceous and later formations, its width is much less.

There are but few good exposures apart from those in the quarries along the Delaware and the Millstone rivers. Over the greater part of this area the character of the soil is determined by the coating of Pensauken and Jamesburg formations, rather than by the rock beneath.

In the ravine at the western edge of Cadwalader park, Trenton, there are heavy beds of arkose conglomerate, with pebbles of quartz several inches in diameter and good-sized feldspar crystals. The rock here is firm and might be used for rough masonry.

Near the canal bridge, a quarter of a mile southeast of the Asylum station, the rock is so completely decomposed that it is spaded out and used for road material and sand. In addition to the constituents derived from the underlying gneissic rocks, there are pebbles of quartzite and sandstone, probably derived from the southwest, where in Pennsylvania these rocks rest upon the Cambrian sandstones.

Hopewell Area.—The second area in which the Stockton series occurs is near Hopewell. Here they form a narrow belt three-fourths of a mile in width, on the southeastern face of the Sourland plateau, extending from Harbourton to near Skillman, a distance of nearly ten miles. They form that part of the escarpment of the plateau which one sees from the railroad near Hopewell, and northeast. The upper limit lies a little west of the crest. These beds are the upper part of the Stockton series, here brought to the surface by

a great fault, located along the foot of the escarpment. The evidence in support of this conclusion will be considered later.

These rocks are, on the whole, somewhat harder than the beds near Trenton and Wilburtha. They are mainly vari-colored sandstones, red-brown, grey and steel-blue predominating, although the weathered fragments are mostly yellowish. The sandstones are quartzose and feldspathic, and, in general, not so free-splitting as those in the Wilburtha quarries. Some beds of heavy arkose conglomerate occur, the most marked locality being half a mile west of Marshall's Corner. A drilled well 106 feet deep, on the Edgerly place, Hopewell, passed through alternating beds of red shale, hard, grey, quartzitic sandstone, brownstone and arkose sandstone. Considering the rapid changes noticed in individual beds in the Wilburtha and Stockton quarries, it is not a matter of surprise that the beds here are somewhat different from those in other localities. There can, however, be no reasonable doubt but that these sandstones belong to the Stockton series. There are no quarries along this belt, and but few large exposures. The character of the rock must be judged largely by the weathered fragments found on the surface. There are a few exposures along most of the small streams, which have incised the face of the escarpment.

The surface is somewhat sandy, and generally strewn with angular weathered slabs of the harder layers. The name Peach Ridge, which in years past was applied to this belt, is indicative of the agricultural use to which the soil was put. Now, however, the term is not particularly appropriate, since peach orchards are as numerous on adjacent areas, and in all the region they are less abundant than they were years ago.

The Stockton Area.—A second great fault brings these beds to the surface again seven miles to the northwest. This third belt extends along the Delaware from Brookville (a mile below Stockton), to a little beyond Raven Rock, having a maximum width of about three miles. Its upper limit extends along the crest of the escarpment of the Hunterdon plateau, the steep slope being formed by the upper beds of the Stockton series, which are here predominantly red shales, with an occasional sandy layer. The lower limit of the beds in this area is formed by the fault, which crosses the strike obliquely, so that the belt becomes narrower to the northeast and finally pinches out midway between Flemington and Sand Brook. The topography of this area is characteristic. It consists of three broad,

low ridges, trending northeast and southwest, parallel to the strike of the beds and formed by the harder and coarser conglomerate members of the series. These are separated from each other by wide, shallow valleys, opened on the softer sandstones and shales. The ridges have an elevation of from 320 to 420 feet, averaging from 100 to 150 feet lower than the neighboring part of the Hunterdon plateau, and rising about 150 to 200 feet above the red shale region across the fault line. Each ridge falls away as the fault line is approached, each higher one in the series overlapping to the northeast the one next lower.

The quarries near Stockton afford unexcelled opportunity for studying the composition, texture and succession of the beds. The rocks here are chiefly free-splitting sandstones of various tints of grey, yellow and red-brown, very similar to those at Wilburtha. Beds of red shale and also conglomerate alternate with the sandstones. In the bluff between Stockton and Brookville, thick beds of very coarse conglomerate occur, the lower beds in this locality being much more consolidated than those near Trenton.

Apart from the exposures in the quarries and a few unimportant outcrops along the streams, the rock is rarely seen. The soil, however, is clearly indicative of the rock beneath, being rather loose, sandy, and often pebbly. Slabs of sandstone and conglomerate strew the surface in great abundance. In color—mostly a grey—and texture the soil is in marked contrast with that of the adjoining regions, which is a red or yellow clay.

North of Flemington.—The fourth area in which the Stockton beds occur lies north of Flemington. The fault which brought the beds in the third area to the surface along the Delaware above and below Stockton, by its oblique course terminated them on the northeast, near Sand Brook. A mile and a quarter north of Flemington, however, they re-appear at the surface, owing to a gradual change of strike from N. 65 E. to N. and N. 20 W. From this point they extend northward to the limits of the formation near Clinton in a gradually widening area, which attains a maximum breadth of three miles in the latitude of Lansdowne.

The beds change in texture and composition within this area as they approach the northwestern boundary. Where they first occur, near Flemington, they consist of coarse arkose sandstones, often much disintegrated and interbedded with soft red shales. The transition to the

overlying series is through several hundred feet of fine-grained, red, sandy shales, agreeing very closely in texture and composition with the uppermost layers above Stockton on the Delaware. Nearer the boundary of the formation the layers of typical arkose conglomerate and sandstones diminish in number and thickness. Their place is taken by beds of red shale, and sandstone and conglomerate of a different type. For four miles southeast of Clinton the basal beds of the formation are found resting unconformably upon red, yellow and dark grey Hudson river slates, Trenton (?) limestone, Cambrian (?) quartzites and gneiss. Material from these formations has entered largely into the composition of the overlying beds, and determined their character. In place of the free-splitting brown and grey sandstones, there occur coarser beds, made up largely of the thin bits of Hudson river shale and small quartzite pebbles. With increasing coarseness of material, we find conglomerates of white, grey and reddish quartzites. Although the Stockton beds rest in part upon the limestone and gneiss, these two rocks occur but rarely in this part of the newer formation. In a final report, the source and origin of this conglomerate will be considered.

Lockatong Series.—Above the Stockton beds there is a series of hard, dark-colored shales and flagstones, which I have called the Lockatong beds. They are, as a whole, much harder and darker than the adjoining beds. They consist (*a*) of carbonaceous shales, which split readily along the bedding planes into thin laminæ, but which have no true slaty cleavage*; (*b*) hard, massive, black and bluish-purple argillites, which break sharply in any direction with a marked conchoidal fracture, but never split into thin layers along the bedding planes; (*c*) dark grey and green flagstones, some layers of which afford slabs nine or ten feet in diameter and three or four inches thick; (*d*) dark, red shales, approaching a flagstone, (*e*) and occasional thin layers of very impure black and drab limestone, or rather highly calcareous shales. There are all gradations between these somewhat distinct types, so that the varieties of individual beds are almost countless.

Some layers are so carbonaceous in appearance as to lead the unskilled to look for coal in the formation. Other layers, particularly some of the argillites, are specked with minute crystals of calcite, and faces of joint planes and cavities are very frequently covered with

* In this connection it may be stated that cleavage across the bedding planes does not occur, so far as I have observed, in any of the Newark beds.

deposits of the same mineral. Minute crystals of iron pyrites occur quite frequently in some layers, but apart from them and the calcite, secondary minerals were not found microscopically in these beds. The red shales are much harder and slightly darker in color than the red shales of the other series. They split into slabs more or less after the manner of flagstones, but do not crumble to minute bits, as does the softer red shale. Their weathered surface moreover is a brighter red than that within, in which respect they are different from the bulk of the red shales, which become slightly darker on exposure to the weather. The limestone beds are very thin and have been noticed only in a few cases.

Not a few writers have called these beds "baked" shales, and have ascribed their hardness and dark color to metamorphism induced by the trap-sheets which occur in the Newark formation. One or two geologists have mistaken some of the exceedingly hard, dense argillite for fine grained trap. The "baked-slate" hypothesis has received apparent support from the fact that one belt of these argillites occurs near the trap of Sourland mountain. There is no doubt but that, in many cases, the trap has produced profound changes both in the color, hardness and mineralogical constitution of the adjoining beds, but the altered beds are not to be confounded with the Lockatong series, and can generally be differentiated from them by careful field work. That the latter are not "baked" shales is shown by the facts (*a*) that they often occur several miles from any known trap-sheet, and that they are just as hard and black at this distance as where near the trap; (*b*) that comparatively soft, thin layers of highly carbonaceous shales occur between beds of the hardest argillite; if the beds of argillite were the result of local metamorphism, it is difficult to understand why the interbedded carbonaceous shales were not also altered; (*c*) the texture and stratification of the Lockatong series is such that they could not have been formed from the red shales by any process of metamorphism. The supposition made by some that metamorphism was produced by great masses of trap which nowhere reach the surface, has absolutely no foundation of fact upon which to rest, and needs no refutation. If any one fact can be accepted as demonstrated by this work, it is that the shales, argillites and flagstones of the Lockatong series are not due to local metamorphism by the trap.

Both ripple-marks and mud-cracks occur at all horizons in the Lockatong beds, showing that shallow water conditions prevailed,

although the materials deposited were exceedingly fine. The mud-crack markings are the more common. Instances were noted where cracks in green or black mud had been filled by red mud, and *vice versa*.

Distribution—Ewingville-Princeton Area.—Owing to faulting, the Lockatong beds occur in several areas, as do the Stockton series. Along the Delaware the width of the first belt is about one and three-fourth miles, commencing three-fourths of a mile above Wilburtha. The lower beds are exposed at Savage's quarry along the canal, and upper layers are shown at Ayres' quarry, Somerset, and near the mouth of Jacobs' creek. Small exposures occur along the canal between these points. The lower limit of these beds is coincident with the upper limit of the Stockton series and extends northeastward through Birmingham, Ewingville, Lawrenceville and Princeton. The upper limit is approximately parallel to the lower, the average width of the belt as far as Rosedale being about two miles.

North of Princeton, the beds which can be referred without any doubt to this series form a belt less than a mile in width. Here the dip of the beds is not, on the average, any greater than where the belt is wider. On the contrary, it is slightly less, so that with the same thickness of beds its width ought to be slightly greater. Between the upper limit of the beds, concerning which there is no doubt, and the trap of the Rocky Hill ridge—three-fourths of a mile distance—there are some green and black shales, which might well be put in the Lockatong series, but the bulk of the intervening beds are soft, crumbly red shales. These seem rather to belong with the subdivision above the Lockatong beds. No such thickness of soft red shales has been found in the Lockatong beds, where the section was most complete. Next to the trap there are pale blue-grey and purplish-red shales, containing amygdules of secondary minerals, the result of metamorphism by the trap. Unfortunately, exposures are wanting at many critical points, so that it has been found impossible to account satisfactorily for the phenomena. (*a*) Whether the Lockatong beds rapidly diminish in thickness east of Rosedale and north of Princeton owing to unknown conditions of deposition, (*b*) whether the beds change lithologically along the strike, so that the red shales between Princeton and the trap ridge are the same horizon as the upper beds of this subdivision further west, or (*c*) whether the upper part of the Lockatong series has been cut out by faulting, it was not possible to

determine. A few cases of crushed and contorted beds and slickensides lend a little plausibility to the last supposition.

There are good exposures of the heavy-bedded, black and dark green argillites at several points along Stony brook below Rosedale, and the quarries of J. K. Brown and Stephen A. Margerum, Princeton, afford good opportunities of studying the various layers. Quarries along the Millstone above (south of) Kingston also show different horizons. East of the Millstone the limits of this subdivision can not be determined with accuracy, owing to the more recent deposits, which conceal all outcrops save along a few streams. Hard, black shale, interbedded with red flags, is found in a small quarry along the railroad a mile and a half due east of Kingston. Along Lawrence brook below Davidson's mills two miles east of Deans, there are also a number of exposures of the dense black argillite. An outcrop of argillite on the Brunswick turnpike southeast of Franklin Park, is probably near the upper limits of the belt in this vicinity, as the region to the north is underlain by soft red shale. The upper limit probably extends from this point eastward to Lawrence brook, near the mouth of Beaver Dam brook, and thence northeast along Lawrence brook, crossing the Raritan river below their junction. The lowest beds exposed along the Raritan river, however, belong to the series next above the Lockatong beds.

Sourland Mountain Area.—The Lockatong series occurs again along the southeastern side of the Sourland plateau, resting upon the narrow strip of Stockton sandstones, which forms the escarpment of this upland. They form a belt, which has here a width of about one and three-fourths miles, the dip being from 15 to 20 degrees to the northwest. As was said above, the backbone of this upland is formed by the outcropping edge of a trap-sheet, a mile in width. From the Delaware river to the village of New Market, the upper limit of the Lockatong beds lies very near the southeastern margin of the trap, the interval being occupied by softer red shales of the third series, which are somewhat metamorphosed near the igneous rock. Near New Market, however, the trap makes a horse-shoe curve, crossing the shales nearly at right angles. As a result of this sharp curve and of a course elsewhere slightly oblique to the beds, the trap along a section between Hopewell and Van Liew's Corners is about 1,760 feet below the upper limit of the Lockatong series. The significance

of this in its bearing upon the conditions of origin of the trap will be discussed below.

Northeast, therefore, from New Market the upper limit of the Lockatong beds is found on the northwestern side of the trap-sheet and about three-fourths of a mile from it. This belt ends about a mile south of Flagtown village, where it is cut off by a great fault. With it terminates the Sourland plateau, whose elevation is due to the hardness and durability of the argillite flagstones and trap.

Numerous exposures of the various beds of this series occur along all of the brooks which flow off the upland to the southeast. Continuous sections are not found, but the outcrops are so numerous that an accurate view of the succession of the beds can be obtained by combining the observations on several streams. It has been found, as in the case of the Stockton series, that the individual beds change somewhat along the strike, both in color and texture, but to a much less extent than do the sandstones. A section across these beds through Woodsville, or southwest, shows a considerable thickness of hard red shales approaching flagstones, interbedded with layers of black and green shale. These grade into black and green shales and argillites to the northeast along the strike, so that, on a section near Amwell, the beds are almost entirely of the latter class and red shale or flagstone layers are very few. Still further northeast hard red-brown shales appear again, but not to their former extent.

A small area of Lockatong beds lies between the Delaware river and Dilts Corner. It is bounded by two faults, which have brought these rocks to the surface. Since there are several trap masses within this area, there was at first some question whether these rocks belonged to the Lockatong series or were metamorphosed red shales. Careful examination shows that they are unlike the altered beds near the trap in other localities, and their extent is to a measure independent of the trap. They were therefore placed with the Lockatong beds. This conclusion, based on lithological likeness, is strengthened by the fact that they pass downward into the arkose sandstones of the Stockton series.

Hunterdon Plateau Area.—The beds of the Lockatong series have their most extended outcrop on the Hunterdon plateau, in the region known as "the Swamp." The conditions which gave rise to this name are due in part to the comparative impenetrability of the rock and the heavy clay soil, which is formed by its decomposition. On

the Delaware the belt begins near the head of Bull's Island above Raven Rock, and extends to a point half a mile north of Tumble, its width being a trifle over three miles. The lower limit is coincident with the upper limit of the Stockton beds until the latter are cut off by a fault northeast of Sand Brook. Thence to Flemington it is limited by the fault by which the hard beds have been brought into contact with soft red shales. North of Flemington they adjoin the Stockton beds, resting conformably upon them. Half a mile east of Sand Brook village an interesting complication in the faulting has brought a narrow strip of the Lockatong beds east of and apparently under the Stockton series.

The upper limit of this belt passes north of Kingwood village, along Mud run in a northeasterly direction; thence, curving gradually to the northward, it passes half a mile east of Oak Grove, and continues in a north by west direction towards Littleton. In this vicinity its location is largely an arbitrary matter, since, as will be shown below, there is here practically no difference between these beds and those higher in the formation.

The width of the belt increases gradually from about three miles along the Delaware to nearly four and a quarter west of Flemington, beyond which it slowly diminishes. The dip of the rocks averages only ten to thirteen degrees in this area as against fifteen to twenty degrees in the Sourland plateau area, so that with the same thickness of rocks, the outcrop would be much wider.

This belt forms a regular curve, parallel to the strike of the beds, which changes from N. 65 E. along the Delaware to N. 10 E. midway between Croton and Flemington, to N. 45 W. near Klinesville, and N. 30 W. near Pittstown. The height of the Hunterdon plateau is due to the wide outcrop, curving strike and hardness of these rocks, and the upper layers of the Stockton series, which have retarded greatly the forces of denudation, so that whereas the adjoining softer rocks have been reduced to an average elevation of under 200 feet, this belt has an elevation of from 500 to 700 feet.

Along the Lockatong and Wickecheoke creeks, which have deeply incised the margin of the plateau, there are fine sections of the beds. Massive black argillite beds and very fine-grained green-black sandstone prevail. The courses of both creeks are marked by rapids and falls, where the water dashes over these harder layers. Hard dark red slates or flags are common near the middle of the belt, and are

well shown on the surface near Locktown. It was found possible to trace some of the more pronounced beds of red flagstone for several miles along their curving strike. This was done in so many cases, at different horizons, as to render it almost certain that this belt is not traversed by faults, and that its width of outcrop is due solely to the great thickness of the beds and the gentle dip.

Modification of the Lockatong Beds.—Midway between Croton and Quakertown these beds begin to lose their typical character. The change is mainly one of texture, but as a result of their increased coarseness, there is also a change in the color, the manner of weathering and the soil formed by their decomposition. The hard black, dark green and dark-red shales and argillites grade into drab, red-brown, green and yellow shaly sandstones.

The prevailing color of the weathered fragments is a light yellow or yellowish brown. It is certain, however, that in many cases, although perhaps not in all, these rocks when fresh were drab, steel-blue, grey, buff or even black, and often somewhat calcareous.

Some beds become slightly arkose, resembling closely some members of the Stockton series. This change occurs *along the strike* and increases in amount as the northwestern boundary of the formation is approached. The change is first noted in the upper beds of the series, and gradually extends to the lower beds as one approaches the border. That is to say, the conditions which favored the deposition of the black shales and argillites extended in the earlier part of the period nearer to the present boundary of the formation than they did during the latter part. Along a section between Cherryville and Quakertown, occasional beds of argillite in the lower half of the series were observed, although most of the beds were yellow or green shaly sandstones. But along a section from Sidney to Littleton, three miles nearer the boundary, almost no traces of the black shales and argillite occur, the nearest approach to them being a very hard, fine-grained black or purple sandstone. Here the beds are chiefly sandstones, largely feldspathic in the lower part, but less so higher in the series. Along Cakepoulin creek there are good exposures of thick red and grey sandstones with occasional pebbly bearing layers, which resemble strongly the Stockton series, but are often somewhat harder. For two miles southeast of Sidney the separation of the beds into the two divisions, Lockatong and Stockton, is almost entirely arbitrary. Yet the sandstones exposed on the Cakepoulin between Sidney and Little-

ton, when traced southward along their strike, are found to grade into the flags, argillites and carbonaceous black shales which underlie "the Swamp."

Pebble-bearing layers, which were first noted along the section between Littleton and Sidney, increase rapidly in thickness and number to the northwest, and within a mile or a mile and a half the series is composed chiefly of massive beds of heavy quartzite conglomerates, which continue to the gneissic rocks. There are so many questions to be discussed respecting the conglomerates along the boundary of the formation that they will be considered more in detail below. It is sufficient to say here that those lying north and northwest of Pittstown are contemporaneous with the fine-grained, dense shales and argillite, and can be traced into them foot by foot through all the intermediate stages. No doubt is held as to the correctness of this correlation.

Soil.—The Lockatong beds give rise to a rather heavy clay soil. The surface is quite thickly strewn with slabs of the argillite and flagstone and on the slopes outcrops are generally abundant. Except in places favorable to the accumulation of the soil from higher slopes, its depth is generally less than five or six feet. On the Hunterdon plateau it is more than usually wet and heavy. This is due in great part to the poor drainage of the region and the comparative impenetrability of the underlying rock. By tiling, the quality of the soil has been greatly improved. Abundant supplies of surface-water can generally be obtained from wells ten to fifteen feet deep, but it is not of the best quality.

Brunswick Shales—Lithological Character.—Overlying the Lockatong beds comes a great thickness of soft shales, with a few sandstone layers. They are predominantly red in color, although a few purple, green, yellow and black layers occur. These are most common in the lower thousand feet of the series, but they also occur at higher horizons. The lower red-shale beds of this series resemble somewhat closely the red shaly flagstones found in the Lockatong series, being somewhat harder than the typical crumbly red shale. In general, this series consists of a monotonous succession of very soft argillaceous red shales, which crumble readily to minute fragments, or split up into thin flakes. Many of the beds are micaceous, and in these layers there is a stronger tendency to split regularly along the bedding planes than in the crumbly layers. More often, the rock will not split

evenly, but rather break up into small, more or less rectangular fragments. Much of it is porous, containing minute irregular-shaped cavities, sometimes empty, often partially filled with a calcareous powder. Calcite veins and crystals are common in some layers.

A few small rhombohedral cavities were seen, such as might be caused by tension in the layers, due possibly to shrinkage subsequent to solidification. Locally lenticular masses of green shale occur in the red. In size they range up to a foot or two in diameter, and vary in shape from nearly spherical to lenticular masses, narrowing down to thin sheets along cracks. They are undoubtedly due to chemical changes by which the red coloring matter of the shale has been leached out.

Although the majority of this series are soft red shales, there are some hard black layers, chiefly near the base, and occasional beds of fine-grained sandstone and flagstones, some of which afford valuable building material. Massive conglomerate beds occur along the northwest border of the formation, a part of which are correlatives of the Brunswick shales.

Evidence that these beds were deposited in shallow water is abundant. Ripple-marks, mud-cracks and rain-drop impressions occur at many horizons. In some quarries impressions of leaves, and stems of trees, or the stems themselves, are frequently found. Their presence in shallow-water formations is to be expected. Beautiful examples of reptile tracks have been found on some layers of these beds, although not in the course of this survey.

Distribution.—The Brunswick shales occupy all the region under discussion, except that occupied by the belts of the other two series and the trap-rocks. They underlie considerably more than two-thirds of the whole area, partly because they are much thicker than the other subdivisions and partly because they form broad, gentle folds.

They are first met with on the Delaware, a short distance above the mouth of Jacobs' creek, whence there is an almost continuous exposure along the canal to Washington's Crossing, a mile and a quarter above. Beds to the thickness of 1,700 feet are shown in this section, including the harder red shales and black layers just above the Lockatong series. They extend along the river to near Moore's, where they are interrupted by the trap of Bald Pate mountain. Their northwestern limit is along the fault-line, which brings up, first, the Lockatong and then the Stockton beds, which form the southeastern half of

Sourland plateau. These rocks extend northeast, with a width of outcrop near the Delaware of four miles, and underlie the rolling country from Hopewell to New Brunswick and beyond.

A second belt begins on the Delaware, just below Lambertville, where the shales next the trap have been much altered and indurated. Its upper limit is at the southern end of the small trap hill, Mount Gilboa, a mile above Lambertville, and extends north by east past Flemington, following the fault-line, which has brought up the Stockton and Lockatong beds of the Hunterdon plateau. The lower or southern limit of this belt follows the Sourland plateau, the lower beds forming the northwestward slope of that highland. At its northeastern end, the two belts of red shale on either side of the plateau unite to form one broad, gently-rolling lowland, the valley of the Raritan river. Standing on the northern end of Sourland plateau—here known as Neshanic mountain—one has a magnificent view of the low plain formed by the Brunswick shales, of the trap-ridges which interrupt its continuity, and of the enclosing highlands. To the west is the Hunterdon escarpment, forming the westward limit of the Brunswick shales and marking the line of a great fault, by which the rocks of the plateau have been uplifted several thousand feet. Thirteen to sixteen miles to the north, across the low red shale plain, are the gneiss highlands, and eight miles northeastward are the curving level crests of the Watchung trap-ridges, which are interbedded in the Brunswick shales, and beyond which the shale lowland extends. No high ground meets the eye to the east toward New Brunswick thirteen miles away, but to the southeast rises the Rocky Hill trap-ridge, at one point deeply cut through by the Millstone and there marking the approximate limit of the Brunswick shales.

Owing to the curving fault-lines and the gentle folds of the strata, only the Brunswick shales are found along a section from New Brunswick to Pottersville, twenty-five miles, across the whole Newark formation as here exposed. The basal beds are here covered by Cretaceous and later formations.* The beds are probably nowhere better exposed in all this area than along the Raritan above and below New Brunswick, where they are easily accessible. Good exposures are found locally along the Millstone, the South Branch and the Neshanic rivers, and also along many of the smaller brooks which drain this region, particularly the short and steep tributaries of the

* A few conglomerate beds near Pottersville, which are the shore equivalents of the red shale, are exceptions to this statement.

Delaware. The beds are extremely monotonous and one good section can serve as a type of them all.

The Brunswick shales are found also above the Lockatong series in the northern and lower part of the Hunterdon plateau. They are exposed in high bluffs along the Delaware from near Tumble station to the crystalline rocks near Holland station, and along the numerous creeks emptying into the Delaware between these points. Black and green shale layers occur somewhat frequently in the lower beds, and are rare, though not entirely absent, in the upper layers.

It was found that the shales of this area when traced along their strike towards the margin of the formation became rapidly coarser, passing, along some horizons, into massive conglomerates. It will be remembered that similar changes were found to take place in the Lockatong beds so that within two or three miles of the margin the distinctions between the three subdivisions are largely obliterated.

Quartzite Conglomerates.—At a number of points along the northwestern boundary of the Newark formation between the Delaware river and Peapack, there are thick accumulations of massive conglomerates. The pebbles and cobbles are chiefly quartzite and hard sandstone of various colors, usually white, grey or pinkish within, although reddish on the surface. These are imbedded in a red mud cement, which, where the conglomerate is heaviest, is just sufficient to coat the pebbles and fill in the interstices between them. Elsewhere the pebbles are scattered more or less thickly in the red mud matrix.

Although the quartzite pebbles are by far the most abundant they are not the only kind. Many layers contain limestones, gneisses and shales or slates. The limestone pebbles not infrequently have been dissolved out of the matrix, leaving it more or less honeycombed. This is frequently the case where the matrix is sandy and there are but few other pebbles. The gneisses are generally much weathered and partly decomposed. All the pebbles are worn and the hard quartzites must have undergone much transportation to have been so completely rounded. The quartzite pebbles in the ledges are traversed by many minute joint planes, the result of dynamic action since they were imbedded. As they weather out, they commonly break without difficulty along these joints, so that the surface is strewn with fragments bounded by one, two or three even-fracture faces and a rounded worn face.

Localities.—The quartzite conglomerates, interbedded with sandstones and shales, are best exposed in the "pebble bluffs" along the

Delaware, a mile and a half above Milford. Of beds here exposed to a thickness of 1,300 feet, 450 feet are conglomerates, 440 feet sandstones, 170 feet shales, and 300 feet hidden by talus. The conglomerate beds are more or less lens shaped, and frequently thin out, to be replaced by beds of different texture. The alternation of the beds betokens shore conditions, and the arrangement of the layers is paralleled by the arrangement of the sand and gravel beds in the shore deposits of the present day. Back from the river these conglomerates form "Gravel hill," so called because the surface is strewn with great numbers of pebbles and cobbles from the disintegrated conglomerate. A mile and a quarter southwest there is another hill of similar conglomerate, smaller and lower than "Gravel hill" and separated from it by red shale.

The heaviest accumulations of the quartzite conglomerate are found underlying the high region stretching northwest from Pittstown and lying south of Pattenburg. This region is known as "the barrens," since the soil is an exceedingly stony clay and the surface is strewn with countless quartzite cobbles, most of which are broken. The rock has disintegrated to considerable depths* over all this region, so that there are no exposures of the conglomerate. There can be no doubt, however, but that it is the same as that exposed in the "pebble bluffs" near Milford.

Quartzite conglomerates interbedded with shales also occur south of Clinton for two or three miles, but they are less massive than those of "the barrens." Hills of the same conglomerate occur along the borders of the formation between a point two miles southwest of Pottersville and Peapack. Four miles north of Peapack there is an outlier of the same rock, forming the hill known as "Mount Paul." Here the conglomerate is surrounded by shales, which have heretofore been considered a part of the Newark system. These beds, however, belong to another period. They are much compressed and folded, and cleave readily along planes transverse to the lines of bedding. They have evidently undergone greater dynamic changes than the Newark shales. Examined more closely they are found to be of somewhat different texture and to present a greater variety of color than the Newark beds. In texture, color and structure they resemble very closely the shales between Pattenburg and Jutland, so well exposed in the cuts of the Lehigh Valley railroad, in which Nason found graptolites. The shales, therefore, near the conglomerates of Mount

* Wells 60 feet deep in the stony clay were reported, but these figures could not be verified.

Paul, which on the geological map of the State are included in the Newark, are in reality Silurian, probably Hudson river.

Rate of Disintegration.—The areas of the quartzite conglomerate uniformly attain greater elevation than the adjoining shale areas. This is not altogether because the conglomerates are more resistant than the shales. Indeed, the depth of soil and subsoil is much greater on the conglomerate than on the shale, and outcrops of rock are practically wanting save in the bluffs along the Delaware. The explanation of the greater thickness of disintegrated material on the conglomerate, and also of the greater height of these areas, is as follows:

As the shale disintegrates the particles are so fine that they can be readily washed down even the gentle slopes, which prevail in the shale areas. Therefore the soil is removed almost as soon as formed, and the rock is continually exposed to the attacks of the weather. On the contrary, the disintegration of the conglomerate gives rise to an exceedingly stony clay, containing cobbles eight to twelve inches in diameter. The finest material—the sandy and clayey matrix—was at first readily washed away down the steep slopes, leaving behind the quartzite pebbles and cobbles, which now form a protective covering and prevent further denudation. The disintegration of the conglomerate goes on beneath this covering more slowly as the residuary layer becomes thicker, and at the same time transportation has been hindered and practically checked by the accumulations of the larger fragments on the surface. Since these contain little or no soluble materials, and can be reduced in size only as they are broken by changes in temperature, the denudation of these areas has been very slow. They form hills rising several hundred feet above the red shale areas.

The Calcareous Conglomerates.—In addition to the quartzite conglomerates, there are others along the northwest boundary composed almost entirely of limestone fragments. A few fragments of sandstone and gneiss occur with the limestone, but they ordinarily form less than one-half of one per cent. of the whole. The limestone pebbles are of various colors, usually shades of blue and grey, sometimes reddish, and set in a red mud matrix, so that the rock has a variegated appearance. Where the conglomerate is best developed, the pebbles are set close together, the interstices between the larger being filled with smaller fragments of the same material. In other layers the red mud matrix is more in evidence, and towards the margin of the conglomerate the rock becomes rather a shale in which are scattered lime-

stone pebbles. The cobbles are on the average six or eight inches in diameter, and in a few localities bowlders three feet in diameter have been seen. The larger fragments are generally worn and rounded, whereas the majority of the smaller are sharp-cornered or at most subangular. This difference was noted at several points and appears to characterize the conglomerate as a whole. Compared with the pebbles in the quartzite conglomerate, the limestones are poorly rounded, a fact of some significance in connection with the origin and source of the materials, since with equal transportation, the limestones, being softer, would have been most rounded. In many places this conglomerate is so pure a limestone that it is quarried and burnt for lime for local use.

Localities.—A small area is found on both sides of the Delaware river, at Monroe, Pa., and Holland Church, N. J. Here it rests against the Palæozoic limestone from which it was probably derived. Another small area occurs near Amsterdam, a mile northeast of the above, from which it is separated by a high hill of quartzite conglomerate. The structure is so obscure here that it is impossible to determine, positively, whether these are at the same or different horizons. The weight of evidence favors the latter view. A third narrow belt extends along the border of the formation from near Spring Mills to Little York, two and a half miles. For a part of this distance, the Palæozoic limestone is known to occur between the gneiss and the calcareous conglomerate, and probably supplied the materials of the latter.

In all three of these areas the conglomerate is interbedded with red shale and sandstone, and contains some gneiss fragments, although not so many as would be expected. from the present proximity of the gneiss.

The largest area of this conglomerate is found along the border of the formation, commencing a mile north of Lebanon and extending to within a mile and a half of Pottersville, a distance of six miles. Its average width is about three-fourths of a mile. It is within this area that the conglomerate is best developed; the fragments are larger and there is a less percentage of non-calcareous matter. It is here, therefore, that most of the quarrying has been done.

Although in this area the limestone fragments are the most numerous and the largest, no limestone is known to exist in the immediate vicinity, from which the material could have been derived. No limestone was found here between the gneiss and the conglomerate, and

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seems to be 4,700 feet. The area is about the same width as that above Trenton, but the dips are much steeper. In the area north of Flemington the angle of dip is very large. If there are no undiscovered faults within this area, the thickness is not far from 6,700 feet. Owing to the changing character of the beds along this section and difficulties of structure, to be referred to later, not much reliance is to be placed upon this estimate.

Of the Lockatong Beds.—The best opportunity for estimating the thickness of the Lockatong beds is on the Hunterdon plateau. Here both upper and lower limits can be carefully located. The dip is more than usually uniform, and outcrops are sufficiently numerous to prevent any great error in the calculation. More than this, the curved course of the belt, and its uniform width, precludes the idea that it is traversed by faults, which follow the strike and repeat the beds.

Along a section a mile east of Kingwood village, the thickness is estimated to be 3,540 feet. Another section, measured near Croton, gave it a thickness of about 3,450 feet, and a third section, near Quakertown, showed a thickness of 3,500 feet. The difference between these results is not more than is to be expected from the manner of computing the thickness (averaging all the dips along the line of the section, and multiplying the width of the outcrop by the sine of the angle). The fact that three independent measurements, made at intervals several miles apart, on a series of strata so curved as these, agree so closely, is strong presumption that these figures are not far from the true thickness of the beds.

It is a more difficult matter to determine the thickness in the Sourland plateau belt. For a part of the distance the beds are bounded by a fault, and the lowest layers of the series are not shown. Then, also, the trap-sheet has been intruded into these beds for a part of its extent, and for the remainder it lies between layers of red shale, just above the upper limit of the Lockatong beds. Owing to the extensive alteration that in places has affected the beds adjoining the trap, it is by no means easy to determine exactly the upper limit of these beds. Along a section northeast of Harbourton, the thickness, exclusive of the trap, is estimated at about 3,600 feet; near Woodsville the thickness was apparently about 3,650 feet. These calculations were made where the entire thickness lies below the trap. Along a section between Hopewell and Van Liew's Corner, the Lockatong beds beneath the trap measure 1,900 feet in thickness, and those above it, about 1,760 feet—total, 3,660 feet. According to these estimates, the

average thickness of these beds in the Sourland plateau belt is something more than one hundred feet greater than in the Hunterdon plateau area. This difference, however, is not greater than would naturally be expected from the difficulty of determining exactly the upper and lower horizons.

Estimates of the thickness of the Lockatong beds in the Ewingville-Princeton belt are as follows: on the Delaware, 1,685 feet; near Ewing, 1,700 feet; near Lawrenceville, 2,500 feet; near Princeton, 1,750 feet, and along the Millstone, 1,800 feet. With the exception of the third (near Lawrenceville) these figures accord fairly well, although they indicate a thickness only one-half that of the other two belts. It is possible that the apparent thickness near Lawrenceville is due to a fault which repeats some of the beds, although no positive evidence of this was discovered in the field. If these figures, 1,700–1,800 feet, represent the entire thickness of the Lockatong beds in this vicinity, an explanation is needed of the lesser thickness of this belt as compared with the same beds in the Sourland and Hunterdon plateaus. Two answers may be given, neither of which is fully satisfactory: First, the beds of the Ewingville-Princeton belt are nearer the shore of the estuary in which these deposits were made than those of the other belts. Stratified deposits have the form of an unsymmetrical lens, thinning out rapidly towards the shore and more gradually seaward. It is to be expected, therefore, that the beds of this belt would be somewhat thinner than those of the others. It may be questioned, however, whether in the case of such fine deposits the difference would be so great as that apparently indicated by these figures.

Second. The subdivisions of the Newark series are purely lithological. It is conceivable, although perhaps not very probable, that the conditions favoring the deposition of the Lockatong beds (mostly black, calcareous or carbonaceous shales and argillites) ended sooner along the Ewing-Princeton belt than they did in the other areas. On this hypothesis the overlying red-shale beds, for a thickness of about 1,800 feet, would be the correlatives in time of the upper half of the Lockatong beds in the other areas, and the upper limit of these beds, as fixed by me, would not everywhere be at the same horizon. According to this hypothesis, sedimentation went on at about the same rate in all the three areas, but the character of synchronous deposits was not always the same. That this last was the case along the northwestern boundary of the formation has already been indicated. As between these two hypotheses the former is the more probable, receiv-

ing some support from the fact that the Stockton beds, below the Ewing-Princeton belt, are also much thinner than those below the Lockatong beds in the Hunterdon plateau.

Of the Brunswick Series.—It is even more difficult to obtain accurate estimates of the thickness of the Brunswick beds than of the other subdivisions. This is due (a) to the monotonous character of the beds, which renders it almost impossible to detect the presence or absence of faults, (b) to the folds in the beds and (c) to the fact that the entire thickness is not present in this part of the State.

West of Ringoes the shales form a syncline, whose axis plunges northwest. Estimates made here show that between 7,000 and 8,000 feet of shales are involved in this folding. Between the mouth of Lawrence brook, east of New Brunswick, and the base of the first trap ridge back of Bound Brook the beds are 10,000 feet thick, if there are no faults in the intervening region. In the bluffs along the Raritan river below New Brunswick three fault breccias were found, but it was impossible to determine the amount of dislocation beyond the fact that it was not sufficient to expose the Lockatong beds, which are here at least 1,000 feet below the surface. From the amount of disturbance which is known to accompany great faults in other parts of this formation, the presumption is that these faults are only small ones. Nothing else was found which in any way lends color to the hypothesis of faults within this area. It would seem as if a deduction of 1,000 feet from the estimated thickness of this section was amply sufficient for any possible repetition of the beds by undiscovered small faults. Nine thousand feet, however, does not represent the whole thickness of the Brunswick shales, since neither their base nor their top is included in this section. They certainly extend for 2,000 or 3,000 feet above the base of the First mountain. In the light of the present facts, an estimated thickness of 12,000 feet for the Brunswick shales does not appear excessive, although in view of the uncertainties connected with the structure, too much emphasis must not be placed upon it. All that can be claimed for this estimate, as well as for all others given in this paper, is that they are made after a careful and detailed examination of the whole area, and rest upon a much larger basis of facts than any previous estimates.

Total Thickness.—Combining the figures given above with those of the other subdivisions, some idea may be had of the probable thickness of the sediments of the Newark system in Western New Jersey:

Stockton	4,700 feet.
Lockatong	3,600 feet.
Brunswick	12,000 feet.
	20,300 feet.

These figures are so great that one naturally hesitates to accept them, but the facts so far as known do not permit any other interpretation. I began my work feeling confident that the thickness of the beds was much less than this, and that they were many times repeated by faults. But at present the weight of the evidence strongly favors the view here stated. Many of the faults found cross the beds at such angles as not to repeat the strata. Furthermore it was possible to check results in a number of instances. The fact that the three estimates of the thickness of the Lockatong beds in the Hunterdon plateau, where the strata curve so markedly, agree closely one with another, and also with the various estimates of the same beds on Sourland plateau, make it improbable that the great thickness there is due to faults. So, too, the thickness of a part of the Brunswick shales involved in a synclinal fold can be quite accurately determined, and the possibility of faulting eliminated. Finding such great thickness in these beds, which are only a part of the whole and where the absence of faults is quite certainly shown, I am the more ready to accept the figures given above. They are, however, not final, but are subject to revision in the light of further work.

Trap-Rocks.—In addition to the sedimentary rocks already described, the Newark formation includes igneous rocks, all of which are included under the term trap. The most important of these have been described in the previous publications of the survey,* and their location shown upon the Geological Map of the State. A few small dikes, heretofore unmentioned, were found during the past season, some of which are of considerable scientific interest. These will be described more at length below.

Origin of the Trap-Sheets.—The trap is igneous in origin. It is rock which ascended in a molten condition to its present position, relative to the surrounding rocks, and there solidified. The Newark trap-sheets may be either intrusive or extrusive in origin. They may have been forced into their present position in the shales and sandstones, while the latter were deeply buried beneath overlying beds, which have since been removed by denundation (intrusive). In this case the molten

* Geology of New Jersey, 1868. Annual Reports for 1879, 1881, 1883, 1884, 1886, 1888.

lava did not reach the surface. On the other hand, the trap may have broken through the sedimentary rocks, spread out over the surface, and then been buried beneath fresh accumulations of sand and mud. In the first case the intrusion occurred after the period of deposition of the inclosing shales. In the second, the lava must have been extruded while deposition was going on. Extrusive sheets, therefore, are older than the beds above them and younger than those beneath them; whereas an intrusive sheet is necessarily younger than the layers surrounding it.

Criteria of Intrusive and Extrusive Origin.—Prof. Davis* has given in much detail the criteria by which these two classes of lava-sheets may be discriminated. The following summary may be made of his discussion:

Intrusive sheets.—

(*a*) An intrusive sheet may break across the beds.

(*b*) Its upper and lower portions are nearly identical, and offshoots may traverse the superincumbent strata.

(*c*) The texture of the mass is in general dense throughout and coarsely crystalline in the middle, but more glassy toward the contacts.

(*d*) A cellular or amygdaloidal structure is rarely developed, and when occurring seems to be confined to the upper portion of the sheet and to be due to replacement.

(*e*) Enclosed fragments of the country rock may be found near the upper as well as the lower part of the sheet.

(*f*) The overlying as well as the underlying beds may be fractured, and friction breccias may be formed.

(*g*) The beds both above and below may be altered by heat, the change being generally in color, hardness and production of new minerals.

On the other hand, the characteristics of extrusive beds are as follows:

(*a*) An extrusive sheet must be conformable to the surface on which it lies.

(*b*) The upper and lower surfaces are strongly unlike.

(*c*) The upper surface may show a ropy flow-structure and may consist of a mass of clinkers.

*W. M. Davis: Bulletin of the Museum of Comparative Zoology, 1889, pp. 100-103.

(*d*) Vesicular texture is very common, especially near the upper surface, sometimes within the mass or, more rarely, at the lower surface.

(*e*) A composite structure, as of two flows, is not uncommon.

(*f*) Vesicles are often drawn out in a common direction and spike amygdules are frequent.

(*g*) The overlying beds show no signs of alteration by heat.

(*h*) The overlying sediments are arranged conformably with the upper surface of the sheet, so that open vesicles and spaces between the clinkers may be more or less filled with the sediments.

(*i*) A trap conglomerate may occur just above the trap-sheet.

(*j*) Extrusive sheets may be associated with ash-beds, volcanic bombs, etc.

The effects of heat and mechanical disturbance in the underlying beds are features common to both kinds of sheets, and the *absence* of induration and apparent complete conformability with adjacent beds cannot be taken as proving extrusion, although they point to that conclusion.

Previous Views.—The earlier workers of the survey were of the opinion that the trap sheets were all intrusive, Professor Cook holding quite strongly to the view that "the red sandstones were at their present inclination before the eruptions which forced the trap-rocks up between the strata of the sandstones."*

Professor Davis† has shown that both intrusive and extrusive sheets occur in New Jersey. First and Second Mountains are overflows, and the Palisades, Sourland Mountain and some other masses are intrusive sheets or dikes. Later, N. H. Darton‡ examined in considerable detail the traps of New Jersey, and agreed with Davis in calling some extrusive and others intrusive. The Palisades, Rocky Hill, Sourland Mountain and the other trap masses in the western part of the State are classed as intrusive. First and Second Mountains, Long Hill, New Vernon trap-sheets, Riker Hill, Hook Mountain and the New Germantown crescent are considered extrusive in origin. Darton's studies did not include the small crescentic ridge of trap southeast of Sand Brook village, not far from Flemington, which is undoubtedly a small extrusive sheet. Other geologists also have added to our information of the trap-rocks.

* Annual Report of the State Geologist of New Jersey, 1886, page 125.
† Davis: Bulletin of the Museum of Comparative Zoology, 1889, pp. 269–279.
‡ Darton: Bulletin of the U. S. G. S., No. 67.

With the work of Davis and Darton the question of the intrusive or extrusive origin of the New Jersey trap-rocks seemed settled. B. S. Lyman,* however, has recently asserted that in Bucks and Montgomery counties, Penn., "there would seem to be no good reason whatever for considering the conformable trap sheets anything but overflows, and any other supposition would now seem very strained." Three of the sheets thus classed as overflows are extensions of sheets in New Jersey, which have always been regarded by all observers as intrusive. Mr. Lyman holds, furthermore, that the Palisades have been regarded by Davis and others as intrusive "for reasons apparently not completely cogent." He cites no facts, however, to support his views beyond the general parallelism of the trap-ridges and the enclosing shales.

It is not my purpose here to repeat the evidence given by previous observers on this subject. Some new evidence, however, was found which bears upon this question and settles it conclusively for several of the ridges. In every case it confirms the conclusions of Davis and Darton on the question of the origin of the trap.

Rocky Hill Trap.—This trap-sheet has been proved not to be conformable with the shales, but to cross the strike at various angles. Where it terminates at the fault-line near Hopewell, it is 6,000 to 7,000 feet above the base of the Brunswick shales, although the exact distance is difficult to determine, owing to several sharp folds in the shales west of Glen Moore and near the end of the trap. The sheet, or dike, cuts directly across these folds. North of Princeton the trap for two or three miles is nearly conformable to the shales, but where it is last seen east of Dean's station on the Pennsylvania Railroad it has reached a horizon in the Lockatong argillites about 1,500 feet below the Brunswick shales. If, as has been suggested by Russell, Davis and others, the Rocky Hill sheet is a continuation of the Palisade trap, there is a still further descent across the sedimentary beds in the buried portion, since the Palisade trap is enclosed between beds of arkose sandstone and conglomerate, the Stockton series. In view of this unconformity, of which there cannot be the slightest doubt, it is impossible to regard Rocky Hill as extrusive in origin.

The Palisades.—Reconnaisance work only has been done along the Palisade ridge, but enough has been seen to convince me that it is intrusive. In addition to the numerous instances of basal unconformity cited by previous observers, the importance of which Mr.

* Lyman: Pennsylvania State Geol. Survey. Final Report, Vol. III, Part II, p. 2,621

Lyman could hardly have appreciated, the upper surface of the trap was found to cut across the sandstones. At the western entrance of the N. Y. S. & W. railroad tunnel, between Granton and Fairview, the upper contact of the trap and sandstone dips westward 18°, whereas the dip of the overlying and indurated sandstones is only 9°. The contact is clearly exposed in the side of the tunnel, and there is no possibility of any error in the observation. About ninety feet of interbedded shale and sandstone are exposed just above the trap, the topmost beds, to all appearances, being as thoroughly altered by baking as those next to the trap. The nature of this contact cannot be mistaken; the unconformity is not such as could have occurred by any possibilities of deposition on an uneven surface; the trap cuts across the layers of sandstone. The upper surface of the trap is not at all scoriaceous nor vesicular; nor are there the slightest traces of trap particles in the overlying sedimentary rocks. The Palisade trap is an intrusive sheet, beyond all doubt. To assert otherwise merely because, in a general way, it follows the trend of the shales, is to ignore evidence of the most conclusive sort.

Sourland Mountain.—This trap-sheet is a continuation of Solebury mountain of Pennsylvania. In New Jersey it is not conformable to the shales. Less than a mile southwest of Rocktown the upper contact line makes a right-angled turn to the northwest for three-fourths of a mile, and then by another sharp turn, resumes its northeast-southwest direction for a mile and three-quarters. Here it turns abruptly again to the southeast for one and a quarter miles, where it again turns to a northeast course, slightly oblique to the shales. The under contact line makes similar bends. By its first turn to the northwest the trap ascends about 1,000 feet geologically, almost directly across the edges of the shales. By its later turn to the southeast, it descends to a horizon about 800 feet lower than its original one. In addition to these abrupt changes of horizon, which are clearly seen on the accompanying map, it crosses the beds obliquely in other parts of its course. It is estimated that along a section between Hopewell and Van Liew's Corners it is 1,800 or 1,900 feet lower geologically than near Lambertville. Southwest of the "horse-shoe" curve, near Rocktown, it is above the base of the Brunswick beds; two or three miles northeast of the curve it is 1,760 feet below the top of the Lockatong series.

But not only is this trap proved to be intrusive by its structural relations. Three trap dikes were found to start from the upper surface

of the sheet, and were traced through the overlying shales for several miles.

The first starts a mile and a half from the Delaware river, ascends about 250 feet and then extends parallel to the main sheet. It can be traced by a line of low outcrops and weathered fragments. For much of the distance its width is not over twenty feet, but it is greater near the junction with the main mass to the southwest. Several shale outcrops were found between it and the main mass. It unites again with the main sheet at the "horse-shoe" curve, over three miles from the starting point.

The second offshoot starts at the bend of the trap southwest of Rocktown and can be traced continuously to Mount Airy, two miles distant, where it is clearly seen crossing the road just south of that village. Where it crosses the creek half a mile east of Mount Airy, it is hardly more than eighteen feet in width and apparently vertical, although the contact with the shale is not shown. The adjoining shale beds are very hard, ashy-gray or pale-green in color, and some layers are marked by segregations of epidote. Other beds are thickly specked with crystals of iron pyrites.

Nearer the main sheet the dike increases in width, and from the amount and distribution of the debris, its width is probably fifty to sixty feet. For much of the distance its course is marked by a line of trees or bushes and uncultivated ground.

The third and longest dike starts from the main sheet, three-fourths of a mile northeast of Rocktown, and can be traced continuously to a point nearly a mile north of Copper Hill, a distance in a straight line of five miles. The slightly sinuous course of the dike increases its length about half a mile. North of Copper Hill station it is interrupted and offset a quarter of a mile to the west, probably by a fault. Thence it continues, more or less interruptedly, to Flemington, two miles distance. Prospect Hill, just west of that place, is a small trap mass, which may have underground connection with this dike, although it does not show on the surface. The copper deposits found years ago near Flemington and Copper Hill occurred in the shales along this dike, and the explorations then made indicate that the dike, even where interrupted on the surface, is sometimes continuous below.

Its width varies considerably, but for the greater part of the distance it is probably between 50 and 90 feet. A quarter of a mile east of the Flemington cemetery, a trap dike, probably the northern continuation of this one, is exposed along the road. Here its width is

from 15 to 18 feet; it dips very steeply to the east, is in fact almost vertical, and the inclosing shales, which are altered to a purplish and yellowish color for a distance of two to four feet from the contact, dip 30 degrees to the west.

The dike can be readily traced by a slight rise of ground, the line of disintegrated material, occasional large bowlders, and a line of trees which have been suffered to grow where the bowlders are the thickest. Near the village of Union it widens suddenly, and from this ganglion another narrow dike extends a short distance towards Union.

The continuity of this dike, between Copper Hill and Sourland mountain, crossing, as it does, the beds at an angle of 45° to the strike, is proof that this part of the red shale area is not traversed by faults formed later than the intrusion of the trap and parallel to the strike, or at a low angle with it. The thickness of the shales thus crossed is between 6,000 and 7,000 feet. This does not exclude the possibility of faults formed before the intrusion of the trap. Since, however, there is some reason for believing that the trap was intruded before the beds were elevated above the sea-level and tilted, the probability that these beds are not faulted at all is quite strong.

The occurrence of these three dikes, in the shales above the trap and their connection with the upper surface of the Sourland mountain sheet, is conclusive proof, apart from the considerations urged by other authors, that the latter is intrusive.

Point Pleasant.—About 500 feet south of Byram station, on the Delaware opposite Point Pleasant, the contact of the trap with the argillite and black shale has recently been exposed. The contact of the trap with the shale dips 40° S., whereas the shales dip 12° northward. Near the trap the shales are somewhat crushed, sheared and slightly reversed in dip, but they are absolutely and completely unconformable, and there can be no doubt but that this unconformity has been caused by the irregular intrusion of the trap. Between this exposure and the depot there is a ravine in which the argillite beds are exposed. Opposite the depot and near the top of the bluff a second trap ledge is found, which is also exposed at Berger's quarry, along the road leading east from the depot up the hill. At first sight it appears as if there were two trap sheets here, but this is probably not the case. The argillite in the ravine between these exposures is beneath the sheet and is exposed only where the stream has cut through the trap. Ascending the ravine to the level of the quarry, there is

strong presumption that the trap crosses the stream, although it was not actually seen in place owing to the numerous large bowlders. There is no indication that the argillite extends up the ravine more than a few rods. This trap, therefore, is proved to be intrusive in origin, although it is the continuation of the Pennsylvania sheet called by Mr. Lyman an overflow.

Bald Pate Mountain and Pennington Mountain.—These two trap masses lie between the Delaware river and the end of Rocky Hill, near Hopewell. No conclusive evidence was found here, but they are believed to be intrusive for the following reasons: (*a*) Their irregular shape does not favor the supposition that they are conformable to the shales. (*b*) Although in places the shales appear conformable, yet many other outcrops were found where the strike of the shales was clearly unconformable to the trap. Unfortunately the outcrops were not so near the trap as to settle this point conclusively. (*c*) The shales near the trap are altered in color, texture, and in the development of secondary minerals. Similar shales occur near those sheets which have been proved to be intrusive. (*d*) The neighboring shales are in some cases contorted and crushed as would naturally be the case where they had been crowded aside by the intrusion of the molten rock. (*e*) The texture of the trap is coarse, resembling that of the intrusive sheets, and never scoriaceous or amygdaloidal, as is often the case with extrusive sheets. In view of these considerations I entertain no doubt as to the intrusive origin of these traps.

Belle mountain, between Bald Pate and Sourland mountain, and Mt. Gilboa, north of Lambertville, are in all probability intrusive, for reasons similar to those urged above. Several trap dikes were found in the vicinity of Gilboa, although in no case was it possible to make out their direct connection with it.

Cushetunk Mountain.—The crescent or horseshoe form of this mountain, between whose curving flanks lies the picturesque Round valley, is certainly striking. The facts indicate quite clearly that this trap mass is intrusive in origin, and that the curving outline is not due, primarily, at least, to an anticlinal or synclinal fold in the shales, but to the curving fracture through which the trap has come. The outline of the trap, as given on all maps heretofore published, has been incorrect. Instead of the broad area of trap on the southwest limb of the crescent, a belt of hard, black and purplish shale from half to three-quarters of a mile in width extends north from Stanton

to Prescott brook. To the west of this shale there is a strip of trap a quarter of a mile wide and a mile and a half long, separated by it from the main mass of the trap.

I am at present by no means certain whether this hard, black shale is soft, red shale metamorphosed by its proximity to the two trap masses, as may well be the case, or whether it is a part of the Lockatong series brought into this position by some complication of the structure. The latter is obscure in this vicinity and outcrops are too few and far between to permit any positive assertions on this point. The former view, on the whole, seems more probable from the character of the rock itself.

No doubt, however, is held as to the intrusive origin of the trap-sheets. (*a*) The trap masses, when examined both in detail and in their general relationships, are found to be unconformable to the shales. (*b*) Apart from the doubtful shales just mentioned, there are others, which have been unmistakably altered in color, hardness and in the production of new minerals. The extent to which the alteration has taken place is roughly proportional to the width of the trap. (*c*) The trap, so far as seen, is always coarse, even very near the contacts. Nowhere was scoriaceous or vesicular rock found. The evidence strongly favors the supposition that it cooled slowly at considerable depths, and never reached the surface. A small dike was found near the end of the southern arm of the curve, but its connection with the main mass could not be established.

The rock of Round mountain, just south of Cushetunk, is similar to that of the former, and the surrounding shales, so far as they could be seen, were somewhat altered. The intrusive origin of this sheet is probable, but not conclusively demonstrable.

Sand Brook Trap.—Half a mile southeast of Sand Brook village there is a low, rounded hill of trap, which heretofore has not been recorded on any published maps. It is about a quarter of a mile in diameter, and the rock is of medium texture. As there are no exposures of the shale near by, its relations to the surrounding beds are not known. There is no indication that they have been at all altered by it.

This hill lies midway between the two hills of a "horseshoe" trap-ridge, the toe of which lies a mile to the southeast. This curving ridge is the outcropping edge of a synclinal sheet, the axis of the fold dipping northwest toward the isolated trap hill. This fold affects the

shales for a distance of over two miles to the southeast and northeast. The trap and the shales are undoubtedly strictly conformable. This favors, although it does not prove, the extrusive origin of this sheet. However, positive proof is not wanting.

The upper surface of this sheet is everywhere extremely vesicular, and only the lower portion is dense and fine-grained. At two places the overlying shale was found less than three feet and one foot, respectively, above the trap. Here there was absolutely no indication of induration, change of color, or development of new minerals in the shale owing to its proximity to the trap. One of these localities was along the road which crosses the end of the southern heel; the other near the road crossing the northern heel at Daniel B. Ege's. At both places the red shale has filled the cavities of the vesicular trap, and at the latter place the shale seems to be underlain by a thin layer of finely-comminuted trap and red mud. Microscopic examinations confirm the conclusions reached in the field.

The under shale, so far as it has been seen in the neighborhood of the trap — which is not often — has not been affected by the trap in any way. The trap itself, where it is not vesicular and scoriaceous, is dark-colored, dense and fine-grained, in texture quite unlike the trap of the intrusive sheets. For all these reasons, I have no hesitation in saying that this trap-sheet is an overflow.

Although this trap lies not far from the hard, black shales exposed near Sand Brook, their induration cannot be ascribed to it, because between them is a great fault of several thousand feet. The soft shales surrounding the trap are far removed stratigraphically from the black shales.

Further details concerning the trap-rock of the Newark system will be reserved for the final report.

METAMORPHOSED SHALES.

Characteristics.—Numerous allusions have already been made to metamorphosed or "baked" shales, which occur near the intrusive trap-sheets. I shall not do more at this time than to indicate, in a general way, the macroscopic changes which have taken place in these beds, and name a few localities where good examples may be found.

The most marked changes caused by the trap are (*a*) a greater or less induration of the shales, (*b*) change in color,—the red shales in general becoming purple and then a blue-black or green near the trap,

and (*c*) the development of secondary minerals,—very commonly epidote and tourmaline. Where the change has not produced definite crystal forms or nodules, an incipient segregation has often occurred, giving the rock a more or less mottled aspect, and on weathered surfaces a warty appearance. This latter characteristic, however, is not limited to the metamorphosed beds, since it has been noted in some layers of the Lockatong beds far removed from any known trap masses.

Of these three changes common in the "baked shales," the third is believed to be the most significant. Mere induration or change of color do not necessarily signify "baking," but when all three occur together, and only in beds in close proximity to certain trap sheets, the most reasonable conclusion is that the changes are due to the igneous rock.

Many of the baked shales, on weathering, become pale blue or ashy grey in color, a tinge never, so far as observed, taken by other layers.

Localities.—These altered shales are well shown in the bluffs at Lambertville, north of the trap of Sourland mountain. Their appearance was so minutely and accurately described, many years ago, by Henry D. Rogers,* then State Geologist, that it is well to repeat it here: "In the quarry northeast of Lambertville [now in the village], we discover the commencement of the change. There the red sandstone, varying but little from its ordinary color, and being only rather more compact, contains a multitude of large, spheroidal nodules of pure green *epidote*, many of which are at least an inch in diameter. They seem not to be distributed promiscuously through the rock, but to be arranged somewhat in layers, parallel to the planes of the strata, though they are often several inches asunder. Two or three hundred feet nearer to the trap we find the rock darker and harder and the number of nodules greatly augmented, though they are generally of much smaller size. The common color of the rock is here a very dull, purplish blue, and that of the nodule a dull black or deep blue. They are of all sizes, from minute specks to the dimensions of a large hazel nut, and possess every shade of distinctness contrasted with the material enclosing them. They seem to consist of some imperfectly formed mineral, apparently tourmaline, in a semi crystalline state. These spherical nodules, or specks, are oftentimes surrounded by a

* Rogers: Geology of the State of New Jersey; a Final Report—pp. 153-4.

crust or coating of another mineral, usually nearly white; and I have remarked that the more obviously formed this crust appears, the more crystalline or fully developed is the interior kernel, which, at this spot, seems to approximate in its features to black schorl or tourmaline. A few hundred feet nearer to the trap, or almost at its base, the rock presents a still different aspect, being of a dark grey hue and somewhat coarse-grained. It seems to have been a standstone, containing little or no clay, as it has nothing at all of the baked, jaspery texture of that previously described, which has plainly been either a shale or a very argillaceous sandstone. This gray rock is specked with innumerable small crystals, of very regularly-formed *tourmalines*, some of which are more than half an inch in diameter."

At Rocky Hill village there are fine exposures of the baked shales which overlie the trap-sheet. They are best seen along the canal, north from the toll-house. Just east of the depot the fine-grained, dense, upper surface of the trap is exposed, dipping 18° northward, conformably to the shale and sandstone in this vicinity. Grey, sandy shale is found about a foot above the trap. It was originally a fine-grained sandstone, and has not been so much altered as the overlying argillaceous shales. The next exposures are some distance above the trap, some layers being drab or green in color, not very hard, with numerous small black nodules—perhaps tourmaline. Beds still further from the trap are an extremely hard, black argillite, characterized by more or less distinct nodules of an oily-appearing green mineral, which in places is so abundant as to form thin sheets, the rock appearing to be made up of black and green laminæ. Still higher in the series occur green, shaly sandstones and black, blue, blue grey and dark red shales, some very hard, others containing black nodules of radiate structure, and still others green nodules of epidote.

On the supposition that here the trap-sheet agrees in dip with the overlying shales, the latter have been greatly changed through a thickness of 600 feet above the trap, and traces of alteration are found for over 200 feet more. Fine opportunity for studying the weathered appearance of the "baked" shales is given along the road from Rocky Hill to Hopewell. Traced westward the thickness of altered shale above the trap decreases in about the same rate as the thickness of the trap diminishes. North of Cedar Grove the highly altered beds are about 400 feet thick, and the change in color can be detected for about 200 feet further. South of Hopewell their thickness

is probably not more than 200 feet at most; the shales, beneath the trap, have also been altered in much the same way, but the altered beds are not so well exposed and apparently are not so thick.

From the exposures near Rocky Hill the following conclusions can be drawn: (*a*) The hardness of the altered beds does not depend upon the proximity of the trap alone. Original texture and composition are important factors. The sandy layers are not so much indurated as the finer shales. (*b*) The color of the beds and the presence and character of the secondary minerals depend largely upon the original texture and composition of the shales. (*c*) There is a gradual transition from the unaltered to the altered shales, and changes in color are the first indications of the alteration. The occurrence of the secondary minerals, however, is better proof that the beds have been locally metamorphosed.

It was found that where the Sourland mountain trap had penetrated the black shales and argillites of the Lockatong series the macroscopical changes were very slight. Crystals of tourmaline and nodules of epidote do not occur, although they are common in the altered Brunswick shales near Lambertville.

Altered shales occur at various points near Cushetunk and Round mountains, but the few exposures are mostly small and there is no good opportunity for noting progressive changes in the shales.

The "baked" shales, which have been reported to occur on the Delaware near Point Pleasant, at various places on the Hunterdon plateau, and along Lawrence brook, are simply the hard, black shales or argillites belonging to the Lockatong series. "Baked" shales surely exist near some of the trap-sheets, but all hard, black shales of the formation are not "baked," as was formerly supposed.

Unclassified Beds.—It has not been possible to classify definitely the beds of the triangular area between Mount Airy, Lambertville and Alexsocken creek. Their structure is complex, dips vary greatly in direction and amount, and in many cases the rocks are greatly crushed and distorted. Two small masses of trap occur within the area, and may have some connection with the main trap of Sourland mountain. Some of the beds are quite certainly metamorphosed red shales, while others resemble more closely the Lockatong series. According to the general arrangement of the beds, we should expect here the normal Brunswick shales, such as occur north of Mount Airy. There has certainly been some faulting within this area, and [illegible]ding, but the exact structure could not be determined.

STRUCTURE.

The general structure of the Newark formation, in the area under discussion, is that of a faulted monocline. That is, the beds dip regularly in one direction, N. 30° W., at an angle of about 12 or 15 degrees, and are traversed by fractures, called faults, which have brought to the surface beds from great depth, causing the same bed to appear several times.

When the structure is examined in more detail it is seen to depart in places from the simple monocline. The beds form several broad and gentle folds, anticlines where the fold is upward, synclines where the fold is downwards. There are in addition a few small and more sharply marked folds, principally near the intrusive trap-sheets and the greater fault lines.

I shall indicate briefly the more important details, as to the strike and dip of the beds, and then take up the question of the faults. Along the Delaware, between Trenton and Titusville, the shales and sandstones have an average dip of 12° and strike N. 55° to 85° E. Near Bald Pate mountain, the trap sheet north of Titusville, the dip increases to 20°. East from the river, towards Pennington and Lawrenceville, the dip averages 15° or 16°, varying from 10° to 22°, the general trend of the beds being N. 55° E., with large local variations. South of Rosedale the dip is as high as 40°, and thence eastward to the Millstone river the beds trend N. 80° to 90° E., and the dip averages about 20°.

Along Stony brook, above and below the Lawrenceville pike, and along this road, rapid changes, both of dip and strike, were found within narrow limits, but in the absence of numerous good exposures, it was not possible to interpret the structure. Strike, N. 30° W., dip 10° S. W.; N. 30° E., dip 50° N. W.; N. 70° E, dip 25° S.; N. 33° W., dip 13° S. W., are a few of the observations made.

North of Bald Pate mountain the dip of the shales is varied both in amount and direction. In some cases the trend or strike is parallel to the outline of the trap-rock, and then near by it is at right-angles to it. Here the beds dip towards the trap, there away from them.

In the brook just west of the southern end of Pennington mountain the shales are seen at intervals for half a mile, dipping southward at an angle of about 20°. The dip then changes to the northward, with an average amount of 10°. At one point along the stream the

metamorphosed and crushed shales near the trap form a small and indistinct anticline. Traces of copper were noted, and at some time in the past an over-sanguine prospector opened here a short adit in the bank.

Between Pennington and Glen Moore the outcropping edges of the shales make a sharp "S" curve. A mile north of Pennington the strike is E.-W., dip 16° N.; half a mile south of Marshall's Corner, N. 40° W., dip 37° S. W.; just north of Marshall's Corner, N. 25° E., dip 30° W., and at Glen Moore, N. 65° W., changing gradually to N. 35° W., dip 30° N. E. Northeast of Glen Moore the strike gradually shifts again to N. 35° E., with dip 12° N. W.

A mile and a half southeast of Glen Moore there is another small fold in the shales, forming a shallow syncline, whose axis is inclined northward. The trap of Rocky Hill, a mile to the northward, cuts squarely across the strike of the beds in this fold.

With the exception of the much-disturbed layers in the triangular area between Lambertville, Mount Airy and Alexsocken creek, the beds of the Sourland plateau are very regular in their trend and dip. The strike is almost uniformly N. 55°–65° E., and the dip averages 17° in the case of the shales beneath the trap near the northeastern end of the mountain, 19°–20° for those above the trap in the same locality and 17° for both overlying and underlying shales along a section southeast from Mount Airy. In general, the dip of the shales just above the trap is a little greater than of those more remote. The dip of the beds of the Hunterdon plateau is quite constant in amount, averaging 11° in the southern and eastern parts and decreasing to 5° at points within a radius of three miles of Frenchtown. The beds are so inclined that their outcropping edges describe a great curve, parallel on the south and east to the escarpment of the plateau. Along Lockatong creek, south of Milltown, the strike averages N. 65°–70° E.; between Flemington and Croton it ranges normally from N. 10°–30° E.; near Klinesville it is N. 45° W., with dip to the S.W., and from Cherryville to Quakertown and Pittstown about N. 20°–30° W. At Frenchtown the beds trend a little west of north, but northward from this place they bend more to the east, so that at Mount Pleasant the strike is about N. 45°–50° E., and at Milford it is N. 75° E. North of Milford, between Spring Mills and the vicinity of Little York, the trend of the shales is approximately parallel to the border of the formation, the beds dipping towards the crystallines at angles varying from 25° to 35°.

Between Pattenburg and Lansdowne the trend of the pebbly shales and sandstones is generally a little west of north, a continuation of the trend prevailing from Cherryville to Pittstown, and the dip is westward. This position of the beds is more or less oblique to the neighboring border of the formation.

South and southeast of Clinton the trend of the shales is closely parallel to the boundary line, and they dip steeply away from it. Near Allerville the strike is N. 35° W., dip 40°-50° W. This region is marked by exceptionally steep dips, locally as much as 85°. In the vicinity of the Round mountain trap there are local disturbances of the beds, possibly caused by the intrusion of this mass.

Between New Brunswick and Bound Brook the position of the shales is very uniform, the strike being generally N. 65°–70° E. and the dip averaging 10°. Similar dips prevail west of New Brunswick as far as Millstone. Between the Millstone river and the Sourland plateau escarpment, south of Harlingen as far as Rocky Hill, the strike of the shales is usually N. 80° E., with dips 18° to 20° N., but swinging a little more to the north near the river opposite Griggstown (strike N. 60°+ E.).

A mile west of Harlingen the beds trend nearly east and west, so that if continued in this direction they would abut against the black argillites of the escarpment. North of Harlingen, at Belle Mead and beyond, they have swung around to the north so that they dip west 15° and trend N. 5° E. Along the line of the Philadelphia and Reading railroad between Belle Mead and Weston and to the east, the shales are about parallel to the line of the railroad (N. 45° E.), with northwesterly dips of 5° to 10°. At Weston there appear to be local folds, but these could not be determined. West of the line of railroad the trend is more northerly (N. 10° E.) and the dips gentle (5° to 8°).

Just west of the station at Flagtown, on the Lehigh Valley railroad, very steep (60°–70°) easterly dips prevail, strike N. 15° W., but they diminish rapidly eastward to 12°, and near Roycefield the westward dips above mentioned are found. The easterly dips prevail towards South Branch, so that a broad, shallow syncline exists between Flagtown and South Branch on the west and Roycefield and Plainville on the east.

South of Somerville, between Roycefield and Weston, the structure is obscure. Much of the region is covered with glacial sand and

gravel, and outcrops are few and discordant in dip. The shales probably form low folds, with dips generally less than five degrees.

North of Somerville, however, the structure is more apparent. The shales, with local exceptions, trend conformably to the Watchung mountain trap-sheet (strike N. 30° W., dip 10° N. E.). Along a line between Lamington and North Branch, the beds are, on the whole, nearly horizontal, no two successive outcrops indicating the same dip. East of this line, towards Pluckamin, the beds in general dip easterly towards the Watchung trap-sheets and underlie them. Locally, there are low arches or rolls in this monocline, which give rise to a few discordant observations. A number of such changes can be observed along the road between Lamington and Greater Cross Roads, and just east of the latter place there can be seen a distortion of the beds caused by faulting, the fault being visible in the roadside.

Between Pluckamin and Bedminster the shales trend a little east of north (N. 10°–15° E), and dip to the east. Northeast of the latter place they swing more to the east (N. 35° E.), still parallel to the recurving trap-ridge. The shales, therefore, which outcrop along Mine brook, northeast of Bedminster, are at the same horizon as those in Washington valley, between First and Second Watchung mountain, back of Plainfield and Bound Brook. The curving outcrop of the trap-sheets, as noted by Cook, Darton and others, is due to a great synclinal fold, in which the shales, as well as the trap, have participated.

Northwest of Bedminster the trend is, at first, N. 80° W., swinging around gradually to N. 35° W., with dips of 30°–35° to the southwest.

West of Lamington and Vliettown the shales appear to form a shallow syncline, whose axis inclines westward, and which includes the crescent-shaped trap-ridge near New Germantown. Near the village the beds dip west; on the north they dip southwest, and to the south and southwest they dip northwest and north.

Within Round valley, between the arms of Cushetunk mountain, the strike is mostly N. 70°-85° E., with dip 25° to 30° N. W. Towards White House and as far as North Branch, the trend is about N. 75°-80° W., with northerly dips. Over the rolling red-shale plain, south and southeast of White House, as far as Three Bridges and Centerville, the shales dip in all directions, at small angles. They are practically horizontal, with gentle undulations, which give rise to

diverse dips, within narrow limits. Owing to the uniformity in texture of the beds, it was rarely possible to trace out these gentle folds.

Southeast of a line from Centerville to Three Bridges, and thence to Flemington, the shales form a regular, northwesterly dipping monocline, the strike being N. 55°–60° E.

Summary.—The monoclinal structure prevails, but not uniformly, although there are no close folds, as in some regions. The beds of the Stockton and Lockatong series are most constant in dip and strike, the monoclinal structure being most marked within these belts, although in Hunterdon plateau the Lockatong beds describe a regular curve of over 90°. Shallow folds, some covering an area of many square miles, prevail in the Brunswick shales. These folds, combined with a fortunate arrangement of faults, as will be shown below, have greatly increased the area of outcrop of the soft shale, and so permitted the formation of the broad, rolling lowland, so characteristic of the greater part of the Newark system.

FAULTS.

General Considerations. — Faulting is said to have occurred when motion has taken place on the two sides of a fracture in such wise that the layers on opposite sides do not exactly correspond. The amount of displacement may be only a fraction of an inch or it may be many thousand feet. The fault plane or plane of fracture may be vertical or inclined at an angle. Its departure from the vertical is termed the *hade.* Those beds which have been depressed, relatively to the layers on the other side of the fracture, are said to be *down-thrown;* the others, up-thrust or *up-thrown.*

When a fault plane is exposed in a rock bluff or similar section the fact of faulting is easily seen, and the lack of continuity on the two sides of the fracture is conclusive proof of such movement. If the displacement be comparatively rapid, and, geologically speaking, recent, the fault line on the surface would be marked by a cliff formed by the up-thrown beds. But when the fault plane is not exposed, and the surface on the two sides of the fault line has practically the same elevation, as is the case when denudation has destroyed the fault-cliff, if it ever existed, faulting is harder to detect. Under favorable conditions, however, it can be demonstrated as conclusively as if the actual dislocation could be seen.

Very commonly the rock surface along the fault plane is scratched or "*slickensided*" as a result of the motion. In other cases the rocks near the plane are crushed, and the fracture is filled with these broken fragments, forming a "*fault breccia.*" The beds of the down-thrown side may be tilted close to the fracture so as to dip away from the fault plane, whereas those on the opposite side may be tilted in the opposite direction. The presence of a fault may therefore be indicated by slickensided surfaces, by a crushed and brecciated zone or by abnormal dips. If all three lines of evidence concur, the case is much stronger than for any one separately. All three, however, may not be conclusive in the absence of other evidence.

Necessarily, the beds on the surface immediately adjacent to the fault line are not exactly the same. If the dislocation has been great compared to the thickness of any of the faulted beds, the rocks on opposite sides of the fault may be very different in color, texture, composition, structure and age. The position of a fault line may often be determined with the aid of these facts.

When the fault has affected beds which are inclined, important results often follow. Suppose the fault plane to be parallel, or nearly so, to the strike of the beds. If the up-throw is on the side towards which the beds dip, beds which outcrop on the other side of the fault line are brought to the surface again and repeated. The more complex the series of beds which is repeated in the same order, the stronger the evidence in favor of a fault. The number of beds repeated depends upon the amount of the fault, the thickness of the beds and the angle of dip.

On the contrary, if the downthrow is on the side towards which the beds dip, some are carried below the surface and do not outcrop at all. Some members of a series might in this way be entirely concealed. The fault might be exceedingly difficult to detect in this case, unless the complete series is elsewhere shown.

If the fault line is parallel to the strike of the beds, the latter will continue indefinitely on either side of the fault. But where it is oblique to the strike, each layer must terminate where it is intersected by the fault. In the case of hard layers forming ridges, it would be found under these circumstances that the ridges would end quite abruptly when the invisible fault line was reached. Topography may, therefore, give a clue to faulting. These are some of the facts upon which the geologist has to depend in trying to locate fault lines in the field.

The Faults of the Newark System.—The Newark system in other States, particularly Connecticut, is known to be intersected by many faults. In New Jersey the earlier workers postulated faults parallel to the strike, in order to avoid the enormous thickness of the beds which must otherwise result from the monoclinal structure. As was shown above, the monoclinal structure is not so continuous as was at first supposed, and part of the width of outcrop is due to gentle folds or horizontal beds. It was not, however, entirely erroneous to assume that faults existed, as they have been discovered by later workers, although by no means in so great numbers as was at first supposed.

Owing to the monotonous character of most of the Newark beds, it is no easy matter to detect faults, particularly those whose throw (amount of dislocation) is less than the thickness of one of the subdivisions made.

Two faults of the first magnitude have been discovered and traced for many miles, the evidence for them being very strong.

THE HOPEWELL FAULT.

Location.—This fault, heretofore unrecognized, extends in a sinuous course from near Moore's station, on the Delaware river, past Harbourtown, Hopewell, and thence, in a northerly direction, along the foot of the Sourland mountain escarpment, passing a short distance west of Flagtown station, on the Lehigh Valley railroad. Its exact location near the Delaware is not certain, but it is probably somewhere between Moore's station and the small trap mass half a mile north. It passes close to the end of the spur of trap a mile and a half west of Harbourtown, and thence, nearly due east, to Pennington mountain, passing just south of Harbourtown. It separates the trap of Pennington mountain from the arkose sandstone on the northwest, which has been brought to the surface by it. Northwest of Marshall's Corner it lies at the foot of the escarpment, which it follows northeastward, beyond Hopewell, nearly to Flagtown. North of Flagtown its course could not be determined.

Evidence of Faulting.—It has already been shown that the Stockton, Lockatong and Brunswick beds occur in the same order on each side of the fault line, all dipping in general northwestward. This repetition of the beds is strong proof of the fault. The alternative hypothesis is

that there are six members in the series, the second three closely resembling the first three, and occurring in the same order. The hypothesis is the more improbable owing to the great thickness of the beds and the close similarity between them. Furthermore, a second fault repeats them again, so that if the fault hypothesis is rejected we must grant nine members to the formation, arranged in three sets exactly alike. The evidence in favor of faulting, however, does not consist alone in the repetition of the beds.

Crushed and contorted shales, slickensided surfaces, and overthrown dips were found at many places along the fault line. They are shown at several points along the stream a mile and a quarter west of Harbourtown, near the end of the trap hill. Southwest of Hopewell the Rocky Hill trap ridge terminates abruptly, its end being separated from the steep slope of Peach ridge by a narrow depression, which marks the fault line, and through which the Philadelphia and Reading railroad passes. The trap in the quarries at the end of the ridge is traversed in many joints, in general parallel to the fault. At other localities, further from the fault line, the rock is not so broken.

In the bed of the first brook east of Hopewell, about 400 yards north of the railroad, a ledge of crushed and slickensided shale and sandstone is exposed, which dips 15° southward. Twenty yards up stream the Stockton beds in the up-thrown block show the normal northwesterly dip, and down stream the Brunswick shales have a strike of N. 15° E., dip 20° west. The fault cannot be more than a few yards removed from the crushed beds.

Similar phenomena occur in the bed of the next brook east, near the foot of the escarpment, not far from the house of David Labaw. Here the Stockton sandstone, in the uplifted block, has been dragged down at the fault line so it dips 72° to the southward.

Again, along the first road south of Plainville, leading onto the Sourland mountain, the fault line can be accurately located. The soft red Brunswick shales have been brought against the hard dark-green Lockatong beds. The contrast in color of the surface of the neighboring fields is striking. Near the fault both rocks have been so completely crushed and afterwards disintegrated that nearly all traces of the bedding planes are destroyed.

Outcrops in the bed of Roaring brook, southwest of Plainville, show the same disturbance. East of the fault line the normal strike of the red shales in this region is N. 55° W., dip 15° N. E., that of the Lock-

atong beds west of the fault is N. 75° E., dip 15° N. W. Five-eighths of a mile west of the Plainville–Skillman road the black shales dip 45° S. E., and are considerably crushed. For two hundred yards up the brook, contorted beds, with slickensided surfaces, parallel to the great fault, occur. There is here every evidence that the beds have been much disturbed, as might be the case near a fault of great magnitude.

In the cut west of Flagtown station on the Lehigh Valley railroad, the shales dip east at angles varying from 22° at the station to 75° three or four hundred yards to the west. Two hundred yards west of the first cut there is a second, in which the beds dip north and northeastward at angles of 15° to 17°. At least two faults occur in these beds, one, perhaps both, being parallel to the great Hopewell fault. The exceedingly steep eastward dips in the first cut and the small faults in the second favor the conclusion that the great fault lies between them, particularly as this point is in line with it.

Still further evidence for the fault is found in the abrupt termination of the different layers where the fault crosses their strike, and the consequent termination of a ridge formed by a hard bed. Just east of Harbourtown a ridge of hard sandstone begins in the upthrown block and extends northeast, the fault here trending more to the east than the sandstone layers. Southwest of Hopewell the Rocky Hill trap-sheet terminates sharply when it reaches this invisible line of fracture. West of Skillman the fault, which here trends more nearly north than the sandstone, cuts across it very obliquely and the belt pinches out. North of this point the fault has brought the soft Brunswick shales against the hard Lockatong argillites. The shales have wasted away much more rapidly than the former, and as a consequence the escarpment is here very steep.

North from Skillman the fault is oblique to the course of the argillites and the trap, which forms the main mass of Sourland plateau, and, as a consequence, the highland comes to an abrupt termination south of Flagtown. It was at first supposed that the trap-sheet would be found to be cut off in turn by the fault, but this does not seem to be the case. It thins out, and finally terminates shortly before the fault is reached.

South of Plainville, the red shale-beds trend at right angles to the fault line, and about squarely against it. Owing, however, to their uniform softness, they do not form ridges, and the evidence from topography is lacking here, but the diverse structure on either side of

the fault is equally conclusive. When all these lines of evidence are considered, it must be granted that the Sourland plateau is bounded on the southeast and east by a fault of great amount, along which the beds on the northern and western sides have been uplifted relatively to those on the southeast.

The Amount of the Fault.—The dislocation has been sufficient to bring to the surface the upper part of the Stockton beds and place them side by side with the middle layers of the Brunswick shales. Estimates in feet of the amount of the fault are accurate just so far as the thickness of the beds involved is definitely known. I have already pointed out the possibility of error in these. On the basis of the figures already given, the amount of faulting is estimated to be something over 10,000 feet.

Northern Extension of the Hopewell Fault.—North of the end of Sourland mountain, near Flagtown, the fault has brought the upper and lower portions of the Brunswick shales against each other. Here the hardness of the beds on the two sides of the fault is the same, and topographic evidence is wanting. So, too, the structure on the two sides is not sufficiently diverse to permit the fault to be located definitely north of the steep dips in the cut west of Flagtown station. Small faults were noted in a ledge near the head of the Raritan Water Power Company's raceway, just below the junction of the North Branch with the South Branch, and in line with the great fault of Flagtown. But the uplift was on the eastern side rather than the western, as should be the case were they closely associated with the Hopewell fault. Several small faults were noted in the shales north of Somerville, but in all cases the uplift was on the east.

There is some evidence that the First mountain, the outer trap-ridge, is terminated by a fault near Pluckamin. Halt a mile south of the end of the mountain the escarpment which, towards Somerville trends N. 33° W., changes quite sharply to N. 8° W., as if cut by an oblique fault. The ridge at the same time rapidly declines in height, and disappears near where the supposed fault would intersect the upper trap boundary. The deep gorge of the North Branch in the crystallines lies to the north in line with the supposed fault.

As opposed to this hypothesis it may be urged, (*a*) that the change in the trend of the trap may be due to a change in the strike of the shales. Observations near the trap, partially at least, confirm this; (*b*) that for two and a half miles from its end the trap has decreased

in width of outcrop, and so in thickness, and its termination near Pluckamin, although somewhat abrupt, is normal; (c) that no direct evidence of faulting, such as crushed beds, slickensided surfaces or overthrown dips, were noted. On the contrary, just where they are to be expected, the shales are conformable with the trap.

The weight of evidence, although not conclusive, is against the hypothesis that First mountain is cut off by a fault. All efforts to locate the Hopewell fault in the red shale valley north of Flagtown have been futile.

THE FLEMINGTON FAULT.

It has been recognized by geologists* that a fault of great magnitude cut the Newark formation below Stockton. In Pennsylvania it has brought to the surface the Paleozoic limestone and quartzite on which the shales rest. Lyman has traced it for thirty miles southwest and west of the Delaware, and published a map† (scale 2 mi. to 1 in.) showing its northeast extension into New Jersey. On this map the fault in places is located two miles from its proper position. On a "conjectural map"‡ of the Newark formation of New Jersey, the error is still more glaring. Although this fault has been recognized in New Jersey, its exact location and extent have not heretofore been worked out.

Location.—A few hundred yards south of Brookville on the Delaware river the bluff is broken by a slight notch. A few yards above this point there is a ledge of coarse arkose conglomerate. Fifty yards below it, there is a small quarry showing crushed and crumpled black shale, in which slickensided surfaces are common. The rock has much the appearance of a fault breccia. The notch, although probably located on the line of a dislocation measuring several thousand feet, is not so marked as the erosion gullies near at hand. From this point the fault extends in a northeasterly direction for about three miles, whence it curves a little, so as to pass half a mile east of Headquarters, two-thirds of a mile southeast of Sand Brook, and a mile west of the center of Flemington. For much of this distance it extends along the foot of the Hunterdon plateau escarpment.

* Lewis, Darton, Nason, Lyman and others.

† B. S. Lyman. Proc. Am. Philos. Soc., Vol. XXXI, No. 142.

‡ Published in Pennsylvania State Geological Survey. Summary Final Report, Vol. III, Pt. II, Plate 597. Also in Proc. Am. Philos. Soc., Vol. XXXIII, 1894, page 194.

Beyond Flemington its course is more nearly north, and at the intersection of the Klinesville and Clinton roads it can be located within a few feet by outcrops of the arkose sandstone on one side and the overthrown Brunswick shales on the other. Its course for a few miles north of this point is somewhat indefinite, owing to the similarity of the adjoining beds. Before considering this doubtful part, let us examine the evidence of faulting, where the line of dislocation has been accurately determined.

Evidence of Faulting.—Along the Delaware river the Stockton, Lockatong and Brunswick beds are repeated by the fault in their regular order. There can be no mistake as to the identity of corresponding members of the series on the two sides of the fault. Not only do they agree closely lithologically, but the thickness of the middle member (the only one completely exposed) in each block is nearly the same. Moreover, the occurrence of the Paleozoic foundation in Pennsylvania in the midst of the Newark beds is a strong argument in favor of this hypothesis.

A second argument is found in the rock structure and the topography. Where the fault was first noted, near Brookville, it is not strongly marked topographically. About a mile to the northeast it follows along a valley between trap and arkose sandstone, but the latter are slightly higher beds than those which bordered it near the river. The trap is intrusive, and the fact that it does not cross the fault line is evidence that the dislocation occurred after the intrusion.

Northeast of Stockton, Sand Ridge, a belt of hard sandstone and conglomerate, extends to Headquarters. The course of the fault is oblique to the trend of this ridge, which ends abruptly when it reaches the fracture just south of Headquarters. A second low ridge of harder sandstone east of Sergeantsville likewise ends when it reaches the fault. Still a third and higher sandstone ridge is terminated for the same reason three-fourths of a mile east of Sand Brook.

At Brookville the fault lies nearly three miles south of the escarpment of the Hunterdon plateau, but a mile east of Sand Brook it reaches the foot of this slope, the entire thickness of the Stockton series having been cut out.

On the southeastern side of the fault, also, there are some interesting examples of truncated structures. The best example of this kind is the syncline between Copper Hill and Headquarters, whose axis is inclined northwestward. The trend of the fault is nearly transverse

to the arms of the syncline and the folded structure is very prettily terminated by the fracture. The small extrusive trap-sheet near Sand Brook is included in this fold and the northern limb of the curve seems to be cut off by the fault.

Further proof is found in the local disturbances which occur along the fault line. These consist of abnormal dips, slickensides, breccias, etc. Allusion has already been made to the crushed black shale below Brookville. Below the mill-pond at Sand Brook a ledge of red shale dips southward 45°, whereas the dip of the shales above the mill-pond is 12° to 15° northwestward. The overthrown dip finds its explanation in the drag of the fault, which is believed to be a little to the south. However, there is a possibility that it lies just north of this ledge, in which case this dip might be due to the synclinal fold mentioned above.

A mile northeast of this locality, in the bed of a brook near Thos. Dalrymple's, there is a ledge of crushed and bent black argillite, traversed by many joint planes with slickensided surfaces. The rock is sharply folded and certainly is not far from the fault. Another instance of similar structure was found a mile west of Flemington, in the bank of Walnut brook, just west of Prospect hill. Here the red shale beds are nearly vertical, but much contorted. Thin layers of green shale in the red emphasize the amount of crushing. Three hundred yards up the brook the Lockatong argillites are found, with normal dip and strike. The fault probably lies near the red shale.

Northeast of Sand brook it has brought the Lockatong argillites against the softer Brunswick shales. As a result the contrast in topography is more marked than where the Stockton sandstones abut against the shales.

Since the beds are repeated by the fault, the up-throw has been on the northwest or side towards which the beds dip.

Amount.—The dislocation at the Delaware river has been sufficient to bring to the surface the base of the Stockton beds. East of Headquarters and Sergeantsville lower members of the Stockton series abut against beds of the Brunswick series, apparently about 2,600 feet above the base.

An estimate of the amount of the throw in feet is subject to the same correction as in the case of the Hopewell fault. It is accurate only so far as the thickness of the beds involved is correctly ascertained. On the basis of thickness already given, the throw of the

Flemington fault near Headquarters is about 10,000 feet. This estimate is based on the assumption that the fault plane is nearly at right angles to the plane of the beds, and that the direction of movement was vertical along that plane.

Half a mile east of Sand Brook village a small fault splits off from the main fracture. Its course is slightly curved, and it is traceable for nearly two miles. By it some of the Lockatong shales of the plateau have been down thrown so that they occur to the east of the Stockton sandstones. Within the area of Lockatong beds inclosed between the two faults, the structure is much confused. Near the Flemington fault the dips are eastward, as if the normal northwestward dip were reversed by the fault. At other points the beds dip in various directions, showing that the rocks are somewhat folded.

Its Extent North of Flemington.—The fault can be accurately located at the intersection of the Klinesville and Clinton roads, two miles north of Flemington. Here fresh exposures (1896) gave the following section.

At the corner a trap mass fifty feet in width was seen. The rock is traversed in every direction by fracture planes, and is much decomposed, but its igneous origin is confirmed by microscopic examination. The trap cannot be traced any distance from this exposure, since the surface is everywhere covered with wash from the higher slopes. Adjoining it on the west is white arkose sandstone, which is much crushed for a distance of 100 feet The dip where first discernible is southwestward, normal for this region. A few yards east of the trap, soft red shales of the Brunswick series are found dipping eastward, at an angle of 20°, the normal dip of the shales being about 20° west. These beds, moreover, are considerably crushed. The fault lies between the shale and arkose sandstone, probably just east of the trap, which may be an isolated block caught in the fault or a dike intruded along the fracture. Its crushed condition favors the former view.

North of this point, the course of the fault is somewhat uncertain. On the west side of the Round mountain trap mass, indurated masses of arkose sandstone were found, which appear to belong to the Stockton series. This being the case, the fault line must be east of these exposures. But the beds on the southeast and east of the trap are unmistakably Brunswick shales. These facts indicate that the trap-mass is in line with the fault. Since the arkose sandstone on the

west side of the trap is considerably indurated, and since the trap itself is not faulted, I am led to the conclusion that faulting occurred before the intrusion of this trap, which ascended along the fault line. Although the facts, as at present known, appear to favor this hypothesis, it is far from being demonstrated.

A strip of Paleozoic limestone projects southward into the Newark formation along Prescott brook, about one and a half miles southeast of Allerville. The Newark beds on the west of the limestone belt dip away from it and evidently rest upon it conformably to its surface. These are the basal beds of the Newark formation. On the east side the shales and fine-grained sandstones dip in various directions, in general towards the older rocks. The relationship is explicable on the supposition that a fault borders the limestone on the east, and that the shales east of the limestone have been depressed relatively to those on the west. This fault continued southward, passes along the western side of a narrow trap ridge, and is directly in line with the Flemington fault further south. The down-throw is, in both instances, on the east.

The arms of Cushetunk mountain trap-sheet terminate against the crystallines. The red shale between them belongs to the Brunswick series. They are exposed a few feet from the crystalline rocks and either dip towards them or at right angles to the boundary line. Thus beds of higher horizons are successively brought against the older rocks. The most rational explanation of this arrangement is that faulting has occurred along this part of the boundary, from a point half a mile west of Lebanon southward to Prescott brook, near the southern arm of Cushetunk mountain. This fault, if it is extended southward along the western margin of the trap, will lie about a mile east of the fault along the limestone mentioned above.

It is highly probable that both these faults are the northward continuation of the Flemington fracture, which may divide near Round mountain, that trap mass being located at the point of separation. However, this is largely conjectural, although it has a strong appearance of truth and offers a reasonable explanation of the structure, so far as known.

THE DILTS' CORNER FAULT.

Another fault was discovered about midway between Brookville and Lambertville. It is located a short distance south of Barbour & Ireland's quarry, where it has brought the trap against unaltered

red shales. Thence it extends in a northeasterly direction, passing half a mile east of Dilts' Corner and uniting with the Flemington fault three-fourths of a mile south of Headquarters. From a cursory examination I am inclined to believe that this fault also unites with the Flemington fault in Pennsylvania, about a mile west of the river. If this is the case, the block between these two faults has a length of about four and a quarter miles and a maximum breadth of nearly one and a quarter miles.

The rocks of this block are Lockatong shales and argillites, underlain north of Dilts' Corner by Stockton sandstones. The general dip is a little south of west, although near the faults there is much diversity. By this fault the hard, black shales have been brought against the softer red shales on the east. The line of demarkation is a sharp one, and is marked by gentle depressions, discernible on the contour maps.

Near the contact line the rocks are in many instances much crushed and shattered. Slickensided surfaces are common, and locally the rock resembles a breccia. The structure of the beds on opposite sides of the fault is not the same, and it is evident that the folds of the one do not affect those of the other.

The fact that the occurrence of this isolated area of Stockton and Lockatong beds is most satisfactorily explained on this hypothesis, affords a strong presumption that the faulting has taken place.

The beds on the east and southeast side have been down-thrown relatively to those on the other side. The combined throw of this fault and of the Flemington fault at this point is about equal to that of the latter further north.

Small Faults.—Faults of a few feet throw have been noted in many cases in quarries, railroad cuts and other exposures. In some cases the amount of dislocation cannot be determined, but there is reason for believing that it is not great. I do not believe that there are other faults in the area examined whose throw is even one-tenth that of the two described. Faults along the border of the formation may be an exception to this statement. The enumeration of these faults, together with many details of structure, is reserved for a final report, when the entire formation within the State shall have been examined.

For a final report, also, is reserved the full discussion of the structure along the northwestern border, some facts of which have already

been stated. There is strong evidence that parts of the border are determined by faults, and that in other parts the basal beds rest unconformably upon the Paleozoic sediments and crystallines.

The conditions under which these deposits were made, the subsequent uplift and faulting, the time and manner of origin of the trap-sheets, and the geographical development of the region, can best be considered after the whole field has been studied. They are also reserved for the final report. Although, in the main, this investigation is purely scientific in its bearings, yet its economic phases have not been neglected, and data of some value have been collected which will be published later.

PART III.

REPORT ON ARCHEAN GEOLOGY

BY

J. E. WOLFF.

REPORT ON ARCHEAN GEOLOGY.

BY J. E. WOLFF, PROFESSOR OF PETROGRAPHY AND MINERALOGY IN HARVARD UNIVERSITY.

The areal mapping of the Franklin sheet of the Atlas of the United States has been completed on the scale of a mile to the inch, and the material is now in course of preparation for publication as an atlas folio. Mr. A. H. Brooks, of the United States Geological Survey, assisted in the work for about two months. A total area of about 200 square miles was thus completed during the season.

One of the results of immediate economic value is the description of the isolated areas of trap-rocks which may be of value for road purposes, and of the large syenite area. The following paper is, therefore, entitled:

THE ERUPTIVE ROCKS OF SUSSEX COUNTY, NEW JERSEY, WITH REFERENCE TO THEIR ECONOMIC VALUE.

During the detailed mapping of the Franklin atlas sheet, which includes a large part of Sussex county, the outcrops of eruptive rocks were examined and located as marked on the accompanying map. As many of these occurrences are in the region of limestone and shale which lies between the the western side of the crystalline rocks of the Archean highlands and the quartzite of Kittatinny mountain, their possible value for local purposes makes a brief description desirable.

The eruptive granite masses which form such a marked feature of the white limestone area and of the crystalline areas lying immediately east and west of it (Hamburg mountain, Pochuck mountain, the Pimple hills, etc.), are not included here, but attention is devoted to the less known areas of the Beemerville

elæolite-syenite and the associated dike rocks, of which a large number of occurrences have been noted. Brief descriptions of many of the localities have been given in former reports of the State Survey and in scientific journals, to which the reader is referred for details as to the mineral composition of the rocks and scientific aspects of the subject.*

Elæolite-Syenite of Beemerville.—This lies a mile and a quarter northwest of Beemerville, forming a ridge just under the crest of Kittatinny mountain and on the east slope, facing Beemerville. The mass of rock has burst through the slates which form the east slope of the mountain at or near their junction with the conglomerate which overlies them and forms the crest of the mountain. It can be called for practical purposes a huge dike, without very definite evidence as to whether its boundaries with the enclosing rocks are vertical or inclined. The length of the outcrop is not quite two miles and the width, taken horizontally, nearly a quarter of a mile. It rises quite abruptly from the flat bench underlaid by slates which forms the slope of the mountain east of it to a height of 250 feet. The rock is poorly exposed to observation, being covered by soil and debris; it varies both in color and coarseness in the different outcrops, but the prevailing tint is gray, either light, dark, or sometimes reddish.

There has been no attempt to quarry the rock, and it is difficult to form an adequate idea of its value from the surface. Judging from the specimens attainable with the hammer it would form a very handsome, massive building stone, of a gray or dark-gray color, which would dress well. The rock is composed of orthoclase feldspar, nepheline, pyroxene and some biotite as essentials, and differs from granite mainly by the absence of quartz and presence of nepheline (elæolite). Studied in thin slices in the microscope the minerals are remarkably fresh, showing little change.

The only similar rock used extensively as a building stone is that of Arkansas, especially from Fourche mountain, near Little Rock. This elæolite-syenite, which is gray or blue-gray, has been extensively quarried both for building stone, paving blocks and road material, and has been used in a number of buildings in

* Reports of 1868, p. 141; 1882, p. 67; 1886, p. 110; 1890, p. 35; and American Journal Science, Vol. 23, 1882, p. 302; 38, 1889, p. 130; 45, 1893, p. 298; 47, 1894, p. 339; Transactions N. Y. Academy Sciences, Vol. 11, 1892, p. 60.

Little Rock and other cities. Its durability, hardness and toughness stand high in the scale. It is quite similar in appearance to the light-gray rock of Beemerville.

Owing to the absence of any deep openings in the rock, and consequent inability to judge of other important qualities, such as structure of the rock, joints, rift, etc., which are so important in quarrying, we can only say that the rock promises well on the surface. One of the best places for development as at present exposed is in the middle of the mass where the old road crosses the mountain. There is a cliff here of the light-gray variety.

The situation of the mass of the rock for quarry operations is excellent, since quarries opened at the east foot of the ridge will have a natural face to work into, with good drainage, room for the disposal of the waste rock, and a down-grade to the road.

The other eruptive rocks are in the form of smaller dikes, some of which represent probably the syenite of the main mass, but in a finer-grained form (elæolite-porphyry), while others are darker colored—almost black—fine-grained, with plates of biotite (mica) in varying amount as the most noticeable constituent.

They are in part the dike rock called, technically, "Camptonite," but for practical purposes can be classed as trap-dikes, as for the one purpose for which they can be used, namely, macadamized roads, they come near to the typical trap-rock of the Triassic area east of the Highlands. The second variety is probably the more valuable, and especially those occurrences containing the least mica, but all, including the porphyry, are better for road metal than any other stone found in the vicinity, and in the future of the county should prove a valuable resource for that purpose, owing to their toughness, compactness and high specific gravity. While all the localities are marked on the map, only the more important masses are here described. The numbers correspond to those on the map.

(1) This hill, which rises 200 feet above the road, has exposures on the southeast side and summit of black trap, which is filled with angular fragments of slate, gneiss, limestone and other rocks—the whole forming a very tough breccia or pudding stone. The larger part of the hill is composed of this rock, although there some slate and other dike rocks intermingled. It is probable, notwithstanding the foreign constituents, that the average

would make a good road material. There is quite a large mass here, as the hill would average 100 to 150 feet in height and is at least 500 feet in diameter and roughly oval.

(2) is a small hill of the same rock in the area of the syenite, and (3) a larger hill near Beemerville, as well as (4), (5), (6), none of which expose such a large area as (1).

(7) is a large dike of elæolite-porphyry about two miles northwest of Deckertown, forming a high ridge; the mass of rock is about 150 feet wide, and exposed 400–500 feet.

(8) This dike, about 700 feet long, 120 feet wide, is a finer-grained, darker porphyry, which would also probably be excellent road material.

Of the other trap dikes,

(9) is 40 feet wide, 600 long;

(10) 100 feet wide, 1,200 feet long;

(11) 15 feet wide, several hundred feet long;

(12) is the continuation of (9) and (10), and comprises three parallel ridges running 800 feet;

(13) is 30 feet wide, 1,200 long;

(14) 100 feet long, 20 wide, and

(15) 50 feet wide, 400 long.

The other occurrences are smaller, and do not need a special description. The well-known dike, 20 feet wide, at the north end of the open cut of the Buckwheat mine at Franklin, (16), and the 12-foot dike in the Rudeville limestone quarries, (17), should be added.

PART IV.

I.

Report on Artesian Wells in Southern New Jersey.

II.

Report on Artesian Wells in Northern New Jersey.

III.

Stratigraphy of the Fish House Black Clay and Associated Gravels.

Fossil Horse, Unio, and Plants.

Records of Borings at Delair and Fish House.

Buried Tree Stumps at Delair, in Post Fish House Beds.

Dinosaur and Associated Molluscan Fossils in Mattewan Cretaceous Clay Marls at Merchantville.

Silicified Tree at Lindenwold.

Fossil Molluscs in Beacon Hill Sands near Millville.

By LEWIS WOOLMAN.

I.

Artesian and Other Bored Wells, and Also Dug Wells, in Southern New Jersey.

OUTLINE.

SIX PRINCIPAL WATER HORIZONS.

In previous annual reports the number of water horizons underneath Southern New Jersey, including both principal and minor horizons, has been defined with some particularity. As it will probably be clearer to the general reader and more useful, we now enumerate only the principal or heavier ones. They are as follows, commencing at the base along the Delaware river and passing eastward so as to reach successively higher and higher horizons:

No. 1, First Horizon—A group. This may be defined as a group of *two or three horizons* in heavy gravel and cobble strata near the base of the plastic clays, which clays are variously colored white, yellow and red, or they are mottled in all these colors. The color of the water-yielding gravels may be defined as a yellowish white in contrast with those on the next higher horizon which are of a bluish white.

No. 2, Second Horizon.—At the top of the plastic clays and base of the clay marls. The water-bearing gravels are often very coarse. Their color is a bluish white in contrast with those of the first group.

No. 3, Third Horizon.—At the top of the clay marls and base of the true greensand marl series, which consist of the upper, middle and lower marl-beds. We designate this the *Marlton-Medford horizon.* It is within the "laminated sands" of Professor G. H. Cook. The water-yielding strata are also bluish white in color.

When boring wells to this horizon its approach is often indicated by the occurrence, first, of the *bryozoa* in the limesand and lime-rock alternations over the Middle Marl, and next by the shell bed in the Middle Marl, of which the two characteristic associated fossils are a *terebratula*, and an ancient oyster, called a *gryphea.* After these, sometimes quite closely after them, and at other times some fifty feet below, there is usually found a hard crust, containing certain straight cigar-shaped fossils, called *belemnites,* and which do not occur in any higher stratigraphical position.

No. 4, Fourth Horizon.—This horizon may be regarded as one not yet thoroughly defined. The only wells so far known tha can draw from it are one each at Winslow and Berkeley, and onet to the 950-foot horizon at Atlantic City. The last well is the same that, through misinformation, was erroneously stated in the report for 1889 to have a depth of 1,100 feet. We designate this the *950-foot Atlantic City horizon.* This horizon is probably at the base of the Miocene and top of the Eocene beds.

No. 5, Fifth Horizon.—About 150 feet higher than the preceding one, and about 125 feet below the base of the great 300 to 400-foot diatom bed. This we designate as the *800-foot Atlantic City horizon.*

No. 6, Sixth Horizon.—About 100 feet higher than the fifth, and ittle below the base of the great diatom bed. This we designate as the *700-foot Atlantic City horizon.*

The finding of diatomaceous clays in the boring of any well is positive evidence that sooner or later, as the drilling proceeds, one or both of the two horizons last named will be found. Unfortunately, diatoms can only be seen with a microscope, and they are therefore not so convenient an indication of their underlying water horizons as the readily visible shells and *belemnites* before noted are of their underlying Marlton-Medford horizon.

Minor horizons yielding much less water than those above listed occur above the sixth or 700-foot Atlantic City horizon, four of which, in Miocene strata, were noted in the annual report for 1894, page 155. Other minor horizons occur between some of the principal horizons now defined, but particularity as to all these minor horizons is omitted for reasons given above.

The three lowest of the leading or greater horizons now enumerated, Nos. 1, 2 and 3, belong to the Cretaceous; the two highest, Nos. 5 and 6, belong to the Miocene. Perhaps No. 4 should also be included in the Miocene list. *

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In previous annual reports the number of water horizons underneath Southern New Jersey, including both principal and minor horizons, has been defined with some particularity. As it will probably be clearer to the general reader and more useful, we now enumerate only the principal or heavier ones. They are as follows, commencing at the base along the Delaware river and passing eastward so as to reach successively higher and higher horizons:

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No. 2, Second Horizon.—At the top of the plastic clays and base of the clay marls. The water-bearing gravels are often very coarse. Their color is a bluish white in contrast with those of the first group.

No. 3, Third Horizon.—At the top of the clay marls and base of the true greensand marl series, which consist of the upper, middle and lower marl-beds. We designate this the *Marlton-Medford horizon.* It is within the "laminated sands" of Professor G. H. Cook. The water-yielding strata are also bluish white in color.

When boring wells to this horizon its approach is often indicated by the occurrence, first, of the *bryozoa* in the limesand and lime-rock alternations over the Middle Marl, and next by the shell bed in the Middle Marl, of which the two characteristic associated fossils are a *terebratula,* and an ancient oyster, called a *gryphea.* After these, sometimes quite closely after them, and at other times some fifty feet below, there is usually found a hard crust, containing certain straight cigar-shaped fossils, called *belemnites,* and which do not occur in any higher stratigraphical position.

No. 4, Fourth Horizon.—This horizon may be regarded as one not yet thoroughly defined. The only wells so far known tha can draw from it are one each at Winslow and Berkeley, and onet to the 950-foot horizon at Atlantic City. The last well is the same that, through misinformation, was erroneously stated in the report for 1889 to have a depth of 1,100 feet. We designate this the *950-foot Atlantic City horizon.* This horizon is probably at the base of the Miocene and top of the Eocene beds.

No. 5, Fifth Horizon.—About 150 feet higher than the preceding one, and about 125 feet below the base of the great 300 to 400-foot diatom bed. This we designate as the *800-foot Atlantic City horizon.*

No. 6, Sixth Horizon.—About 100 feet higher than the fifth, and ittle below the base of the great diatom bed. This we designate as the *700-foot Atlantic City horizon.*

The finding of diatomaceous clays in the boring of any well is positive evidence that sooner or later, as the drilling proceeds, one or both of the two horizons last named will be found. Unfortunately, diatoms can only be seen with a microscope, and they are therefore not so convenient an indication of their underlying water horizons as the readily visible shells and *belemnites* before noted are of their underlying Marlton-Medford horizon.

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We now present the records of the wells in Southern New Jersey in order, under the following heads:

Sec. 1a.—Wells in the southern part of the Cretaceous belt.
Sec. 1b.—Wells in the northern part of the Cretaceous belt.
Sec. 2.—Wells in the Miocene belt.
Sec. 3.—Wells in recent strata.

Sec. 1a.—Wells in the Southern Part of the Cretaceous Belt.

BORED WELL AT PENNSYLVANIA RAILROAD CAR SHOPS AT PAVONIA, NEAR CAMDEN.

Elevation, 30 feet; depth, 152 feet; diameter, 6 inches to the depth of 55 feet, 2 inches below that depth.

In the Annual Report for 1892, page 308, there is a notice of four borings at the Pennsylvania Railroad car shops at Pavonia, with depth of 192, 82, 67 and 60 feet. The last one, known as Well No. 4, has been deepened recently by Mr. W. H. Knowles, who furnishes us the following record, accompanied by an excellent series of specimens. The former boring had, however, filled up some five feet, so that the present record commences at that depth, viz., 55 feet:

Specimen Number.	Kind of Material.	Thickness of Stratum.	Total Depth from Surface.
	Surface to 55 feet. See report 1892, p. 308	....	55 feet
1	White sand	13 feet	68 "
2	White sandy clay	5 "	73 "
3	Fine white sand	2 "	75 "
4	White clay	3 "	78 "
5	White sand	1 "	79 "
6	Yellow sand	2 "	81 "
7	White sandy clay	6 "	87 "
8	White sand	6 inches	
9	White sandy clay	5 feet	92 "
10	White fine sand	1½ "	93½ "
11	White clay	6 inches	94 "
12	White fine sand	3 feet	97 "
13	Yellow clay	2 "	99 "
14	Red clay	6 "	105 "
15	Yellow clay	4 "	109 "

16	White sandy clay..............................	8 "	117 feet
17	Very fine hard-packed white sand, almost as hard as sandstone........	5 "	122 "
18	White sandy clay..............................	7 "	129 "
19	Fine white sand..............................	18 "	147 "
20	Gravel, with coarse sand..................	5 "	152 "

CAMDEN ARTESIAN WATER-SUPPLY—FOUR WELLS NORTH OF DELAIR, THREE WELLS AT CRAMER HILL FERRY.

Seven experimental wells have been put down for the purpose of furnishing the city of Camden with a supply from the water horizons that are interbedded near the base of the plastic clay series of the Cretaceous, which horizons are now furnishing a satisfactory quality of water to the city of Gloucester. Four of these wells are on the meadows adjacent to the Delaware river, north of Delair, and three directly on the river's edge, a short distance north of Cramer Hill Ferry.

Six of these wells were put down by Kisner & Bennett by the hydraulic process, and one, the central well at Cramer Hill, by George H. Orcutt, who used the drill and sand pump, an excellent method for the obtaining of specimens of the strata unmixed and in their original condition.

Both contractors have courteously furnished samples of the borings and information as to the details of tho different wells from which we are able to present the following facts.

WELLS NORTH OF DELAIR.

Three water horizons as follows :

No. 1, depth 43 feet to 61 feet.
No. 2, depth 85 feet to 100 feet.
No. 3, depth 110 feet to 150 feet.

The wells north of Delair are arranged lengthwise of a tract of about 200 acres of land west of the railroad, a line joining them being approximately parallel both to the railroad and to the river. They demonstrate that a large amount of water at three different horizons underlies the tract. The water from each horizon rises about to tide level or nearly to the surface.

At Thorofare. Four wells.
At Paulsboro. Two wells.
At Billingsport.
At Clarksboro (test-boring only).
At Mickleton.
At Swedesboro (unfinished and abandoned well).
Near Harrisonville.
Near Auburn.
At Pitman Grove.
At Barnsboro. Three wells.
At Glassboro and Clayton.
At Mantua.
At Magnolia.
At Laurel Springs. Two wells.
At Lindenwold. Two wells.
Near Clementon.
At Cropwell.
At Middletown (Del.)
At New Castle (Del.), two wells.
At Hares Corners (Del.)
At Reedy Island (Del.)
At Farnhurst (Del.)
At Locust Grove (school-house).
At Milford.
At Buddtown.
At Bordentown, test-boring.
At White Horse, three test-borings.

Sec. 1b.—Well Records in the Northern Part of the Cretaceous Belt.

At North West Asbury Park.
At Holmdel.
At Lakewood. Two horizons.
At Belmar. Three horizons.
At Bay Head and north of (two wells).
At Mantoloking. Three horizons.
At Toms River.
At Barnegat Park.
At Barren Island, Long Island, N. Y. Two wells.

Sec. 2.—Well Records in the Miocene Belt.

At Belmar.
At Mantoloking.
At Harvey Cedars.
At Atlantic City, The Dennis.
At Atlantic City, The St. Charles.
At Atlantic City, The Rudolf.
At Atlantic City, The Haddon.
At Atlantic City, The Garden Ho

At Ocean City.
At Clayton (Del.)
At Sea Isle City.
At Milford (Del.)

Sec. 3.—Well Records in Recent Strata.

At Sandy Hook.

INTRODUCTION.

The certainty of obtaining water by means of deep-bored wells in southern New Jersey is now so thoroughly established that each year more and more such wells are being put down. Heretofore these wells have been mostly adjacent either to the Delaware river or to the Atlantic coast, but latterly a number of bored wells have been sunk in the interior, where water horizons can just as certainly be reached. In fact, the first deep-bored well in southern New Jersey was located at Winslow, in the heart of the central belt.

We present detailed records of borings that have come to our notice this year. As in former reports they are classified into those that draw from Cretaceous beds and those that draw from Miocene beds. The Cretaceous underlies the Miocene, the Eocene, however, intervening; but as we know of no water-bearing strata in this State within the Eocene, there are no wells to classify under it. Passing from the Delaware river to the ocean, the Cretaceous, Eocene and Miocene pass one beneath the other successively in the order named, all dipping to the southeast. Consequently borings entering Miocene strata after finding water horizons within the same can be continued so as to find other and lower horizons within the underlying Cretaceous; conversely, however, wells entering immediately near the surface into Cretaceous beds cannot draw from the Miocene but only from Cretaceous water horizons.

On account of these relations of underground structure the wells in the Cretaceous are mostly west of a line drawn northeast and southwest through Winslow, while those in the Miocene are are east of same line.

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150 feet east of Well No. 1. The record as furnished by Wm. H. Boardman is as follows:

Marsh mud	3 feet.		
Muddy sand	3 feet =	6 feet.	
Sand and gravel	4 " =	10 "	
White sandy clay	1 " =	11 "	Cretaceous.
Yellow clay and sand	3 " =	14 "	
Coarse white sand	1 " =	15 "	
Clay and gravel	1 " =	16 "	
Light colored, coarse yellow sand	12 " =	28 "	
White sandy clay	1 " =	29 "	
Very fine white sand	3 " =	32 "	
Light yellow sand, a little coarser	4 " =	36 "	
Light yellow sand, still coarser	6 " =	42 "	
Very fine yellow sand, with small stones	3 " =	45 "	
Gravel	2 " =	47 "	
Stiff white clay with thin yellow streaks	2 " =	49 "	
White clay	7 " =	56 "	
Very coarse gravel and stones	24 " =	80 "	
Clean, coarse white sand	1 " =	81 "	
Coarse, white sand and stones	29 " =	110 "	
Black Clay	3 " =	115 "	

Rock at 115 feet.

WELL NO. 3, AT CRAMER HILL FERRY.

Elevation, 5 feet 4 inches above mean low water; diameter, 6 inches; depth, 126 feet to rock.

This well was bored by Kisner & Bennett. It passed through practically the same succession of material that was penetrated by the two wells whose records precede this.

TEST BORING, CAMDEN, N. J., NEAR FRONT AND ELM STREETS.

Elevation, 10 feet; diameter, ; depth, 115 feet 2 inches. To disintegrated rock at 95 feet.

William H. Knowles, of Camden, kindly furnishes the following report of a test boring made in that city, near Front and Elm streets. We insert his record verbatim, except that we omit

inches when there are less than six, when more we count them as one foot:

Specimen Number.	Kind of Material.	Thickness of Stratum.	Total Depth from Surface.	
1	Top soil	7 feet.	7 feet.	
2	Gravel	11 "	18 "	
3	Sandy clay	5 "	23 "	
4	Sand	7 "	30 "	
5	Blue clay	14 "	44 "	
6	Gravel	20 "	64 "	Water in this 70 gallons a minute.
7	Dark clay	4 "	68 "	
8	Gravel	6 "	74 "	
9	Fine white sand	4 "	78 "	
10	Gravel	7 "	85 "	Water in this 50 gallons a minute.
11	Coarse sand	4 "	89 "	
12	Gravel	4 "	93 "	Water quantity same as No. 10.
13	Yellow clay	2 "	95 "	
14	Soft mica rock	20 "	115 "	

Hard bed-rock at 115 feet.

TWO BORED WELLS AT SEVENTH AND KAIGHN'S AVENUE, CAMDEN.

Water horizon at 53 to 63 feet, not satisfactory.
Water horizon at 90 to 101 feet, satisfactory.

The Farr & Bailey Manufacturing Company write as follows respecting two wells at their oil-cloth factory at the above locality:

"We have two wells, 3-inch bore, situated about twenty-five feet apart, one of which is 90 feet 7 inches in depth, and the other 101 feet 5 inches. When these wells were first bored, we stopped at 53 and 63 feet, repectively, but the water was unfit for use in the boilers, so we had them bored to the depths above mentioned.

"The water is perfectly clear, and, while we have never measured the quantity which the wells will deliver, we find that our duplex Worthington pump is fully supplied, even when pumping constantly. The size of the pump is 7½ x 5 x 6.

"We kept no record of the strata passed through. The gravel from which we are now getting the water is composed mostly of white stones about the size of a pea."

Both the water horizons noted are undoubtedly in the gravels interbedded within the plastic clays.

TEST BORINGS IN CAMDEN, NEAR HADDON AVENUE STATION.

Elevation, 20 feet; diameter, 2 inches; depths, 75, 92 and 105 feet. Water horizons at 75 and 92 feet.

Four test borings were made in 1895 by P. H. & J. Conlin, preparatory to the erection of an armory near Haddon avenue station, Camden. Sets of specimens from three of the wells were courteously furnished by the contractor. The borings were made to varying depths, viz.: to 75, 92 and 105 feet, the surface being nearly level and the elevation about 20 feet. Water was first met with at the depth of 20 feet, and again at 75 to 92 feet—the latter horizon is in the bluish gray sands that underlie the clay marl series and overlie the plastic clays. The water from this horizon rose to within 15 feet of the surface.

From an examination of the specimens the following record has been made:

10 feet	coarse sand and gravel	10 feet.	
30 "	whitish or gray sand	10 to 40 "	
30 "	black mud (clay marl)	40 " 70 "	Cretaceous.
20 "	Bluish gray sand	70 " 90 "	
15 "	Yellow sand	90 " 105 "	

ARTESIAN WELL IN CAMDEN, N. J., AT THE AMERICAN NICKEL WORKS.

(Elevation, 5 feet; diameter, 6 inches; depth, 105 feet).

Kisner & Bennett, early the present year, drilled a well on Cooper's creek, at the foot of Tenth street, Camden, for the American Nickel Works. The depth reached was 105 feet, water being found in coarse gravel near the base of the plastic clays, the stratification being mud, the same as that of the wells reported page 108, near Haddon avenue station. The water rises about to tide level.

BORED WELL IN CAMDEN, ON DELAWARE RIVER, FOOT OF COOPER STREET.

Bored to the depth of 95 feet to rock; finished at the depth of 59 to 62 feet.

George J. Kennedy reports having sunk a well to the depth of 95 feet for the Ammonia Works on the Delaware river, at the foot of Cooper street, Camden. The top of the micaceous bed-rock of the Azoic belt of southeastern Pennsylvania was struck at the depth of 86 feet. The record is as follows:

River mud (a few feet of made ground on top)			43 feet.
Blue clay	43 feet to	59	"
Gravel, various-sized pebbles, size of peas, filberts and cherry stones; water-bearing	59 "	62	"
Clay and sand	62 "	70	"
Dark, cream-colored clay	70 "	86	"
Soft, micaceous rock	86 "	95	"

This well was finally finished at the depth of 59 to 62 feet, so as to draw a supply from the coarse gravel between those depths.

BORED WELL IN CAMDEN, AT THE POWER-HOUSE OF THE CAMDEN RAILWAY COMPANY.

Elevation, 5 feet; diameter, 6 inches; depth, 147 feet.

To Geo. H. Orcutt, contractor, we are indebted for the following record of a well at the power-house of the Camden Railway Company, on Cooper's creek, near Market street cossing:

Black mud		10 feet.	
Sand and loam	17 feet	= 27 "	
Sand like Jersey sand	47 "	= 74 "	Cretaceous.
White sand	21 "	= 95 "	
White clay	1 "	= 96 "	
Red clay	12 "	= 108 "	
White clayey sand	2 "	= 110 "	
Mixture of red sand and clay	18 "	= 128 "	
Sand	12 "	= 140 "	
White clay	3 "	= 143 "	
Sand and gravel	4 "	= 147 "	

BORED WELL IN CAMDEN, ON LOT EAST OF CITY HALL.

Elevation, 20 feet; diameter, 4½ inches; depth, 72 feet.

To George H. Orcutt, contractor, we are also indebted for the following record of a well put down by him on the lot east of the City Hall, also for the Camden Railway Company:

Clay	12 feet.	
Sand	14 feet = 26 feet.	
Dark mud	9 feet = 35 feet.	
Sand	10 feet = 45 feet.	
Sand and loam mixed	9 feet = 54 feet.	
Green sand (?)	9 feet = 63 feet.	Cretaceous.
Sand	4 feet = 67 feet.	
Gravel	5 feet = 72 feet.	

BORED WELLS, CAMDEN, N. J., AT THE UNITED STATES CHEMICAL WORKS.

Elevation 5 feet { Well No. 1, depth 134 feet. Water horizon 125 to 134 feet
Well No. 2, depth 47 feet. Water horizon 44 to 47 feet.

Through the kindness of George H. Orcutt, contractor, we have been furnished with the following record of a well (No. 1) put down by him at the above named chemical works.

Ashes and made-ground		15 feet	
Dark sand	3 feet	= 18 "	
Dark brown clay	2 "	= 20 "	
Dark brown sand with streak of clay	26 "	= 46 "	
Gravel	3 "	= 49 "	
Red clay	53 "	= 102 "	
Yellow sand, with streaks of white and red clay	10 "	= 112 "	Cretaceous.
Whitish sand	13 "	= 125 "	
White sand and gravel	7 "	= 132 "	
White sand with not so much gravel	2 "	= 134 "	

The well is supplied from the sands and gravels at 125 to 134 feet. They are near the base of the plastic clay division of the Cretaceous of this State.

Another well (No. 2) was put down at the same place to a depth of only forty-seven feet, drawing a small supply from the three feet of gravel at that depth.

BORED WELL IN CAMDEN, AT THE COUNTY PRISON.

Elevation, 20 feet; diameter, 6 inches; depth, 157 feet.
Water horizon depth, 130 feet to 138 feet.

Geo. H. Orcutt, contractor, kindly furnishes the record below of a well put down by him in the basement of the county prison, at the corner of Sixth and Federal streets, Camden:

Sand, gravel and loam			to 24	feet.	
Black mud	24	feet to	42	"	
Chocolate clay	42	"	66	"	Cretaceous.
Yellowish sand	66	"	88	"	
Gravel, with irony water.					
Dark clay	88	"	106	"	
Gravel, with irony water	106	"	113	"	
Alternations clay and sand	113	"	130	"	
Heavy gravel, with good water	130	"	138	"	
Soft micaceous rock	138	"	157	"	
Hard rock at			157	"	

This well was finished with ten feet of four-inch strainer so as to draw from from the heavy gravels next above the soft rock at the depth of 130 to 138 feet.

BORED WELL IN PHILADELPHIA, PA., AT SEVENTEENTH AND WASHINGTON AVENUE, IN BEDS BELONGING TO THE NEW JERSEY SERIES.

Elevation, 25 feet; depth, 67 feet; water rises to within 25 feet of the surface.

This well was put down for the Consumers Ice Company.

RECORD.

Depth of cellar	10	feet.	
20 feet gravel, slightly yellowish	10 to 30	"	
25 " gravel, bowlders, sand and mud	30 " 55	"	
1 " white plastic clay	55 " 56	"	Cretaceous.
11 " gravel, sand and bowlders, from which the water-supply for this well is obtained	56 " 67	"	

The strata below the depth of fifty-five feet, if indeed not all below thirty feet, belong to the basal plastic clays and gravels of the New Jersey series.

BORED WELL IN PHILADELPHIA, PA., AT EIGHTH AND CATHERINE.

Elevation, 25 feet; depth, 92 feet.

The record of the well at this locality was obtained from the man engaged in putting down the well just reported at Seventeenth and Washington avenue. It is as follows:

40 feet	sand and gravel, surface to	40 feet
20 "	black mud, described as river mud (?)	40 to 60 "
32 "	gravel, light yellowish color	60 to 92 "

Water-bearing at 70 to 92 feet.

Certainly, all below the depth of at least 60 feet belongs to the base of the New Jersey Cretaceous plastic clays and gravels.

BORED WELL IN PHILADELPHIA, AT MOORE STREET WHARF, ON THE DELAWARE.

Diameter, 3 inches; depth, 150 feet.

W. R. Kelly furnishes the record below of a three-inch well at Moore street wharf, on the Delaware river, put down for the Baugh Phosphate Company:

6 feet filled-in earth			6 feet.	
40 feet black river mud	4 feet to		46 "	
5 feet stiff, dark clay	46	"	51 "	
7 feet coarse gravel, pebbles large as walnuts; water irony	51	"	58 "	
50 feet stiff, red clay	58	"	108 "	
8 feet shifting sand, with water	108	"	116 "	Cretaceous.
19 feet sand and clay	116	"	135 "	
7 feet yellow clay	135	"	142 "	
8 feet coarse gravel, size of peas and chestnuts; water	142	"	150 "	

The water rises about to tide level. The strata below 51 feet, and probably below 46 feet in depth, belong to the base of the New Jersey Cretaceous.

BORING AT POINT BREEZE GAS WORKS, PHILADELPHIA.

Elevation, 25 feet; depth, 96 feet.

Some years since there was a boring made opposite the lower end of the retort house, at the Point Breeze gas works, Philadelphia, on the eastern side of the Schuylkill river, two and one-half miles northwest of the well at the navy yard noticed on another page. We have been informed that the following succession of strata was passed through:

10 feet gravel	10 feet.		
40 " sand	10 feet to 50 "		
16 " clay	50 " 66 "	}	Cretaceous.
10 " white sand	66 " 76 "	}	Cretaceous.
20 " gravel	76 " 96 "	}	Cretaceous.

From the evidence presented by other well sections, some of which are noted in this report, we should regard all the beds below at least the depth of 50 feet to be Cretaceous, and to represent the gravels and clays of the New Jersey plastic clay series.

BORED WELL AT THE ATLANTIC REFINERY, POINT BREEZE, PHILADELPHIA.

Elevation, 10 feet; depth, 56 feet.

Through the courtesy of the president and secretary of the Atlantic Refining Company, we have received a series of the borings, from which we make the following record:

(*a*) Yellowish, loamy clay	8 feet.
(*b*) Darker, sandy clay	8 feet to 10 feet.
(*c*) Heavy gravel, same color as *b*	10 " 18 "
(*d*) Heavy gravel, yellowish, as *a*	18 " 25 "
Dark clay	25 " 33 "
Brownish clay	33 " 45 "
Brownish sand, with water	45 " 56 "

Microscopic examination of all the clays in the above well was made, resulting in not finding either diatoms, sponge spicules or other micro-organisms.

ARTESIAN BORING AT THE U. S. NAVY YARD, LEAGUE ISLAND, PHILADELPHIA.

Depth to gneiss rock	270 feet.
Depth in gneiss rock	180 "
Total depth	450 "

Boring not yet completed.

A well has been bored at the United States Navy Yard at Philadelphia. The location is upon League Island, at the junction of the Schuylkill and Delaware rivers. The work was done by P. H. & J. Conlin, who carefully saved and presented a very full series of the borings taken every few feet to the rock, which was met with at the depth of 260 feet. The borings were taken less frequently afterward.

The section, as revealed by the borings, is as follows:

Marsh mud, alluvium			to 19 feet.	
Fine gravel	19 feet	to	40 feet.	
Heavy gravel as large as shellbarks	40	"	50 "	
Coarse gravel	50	"	55 "	Cretaceous.
Coarse sand and gravel with some bluish white clay	55	"	66 "	
Sand and gravel	66	"	83 "	
White clay, tough	83	"	85 "	
Red and mottled clay, tough	85	"	110 "	
White, coarse sandy clay	110	"	140 "	
Medium sand, whitish	140	"	148 "	
Coarse heavy gravel	148	"	155 "	
Medium sand, whitish	155	"	162 "	
White clay	162	"	178 "	
Whitish sand, medium fine	178	"	195 "	
Yellowish white sand, coarser	195	"	205 "	
Very heavy gravel, cobble, &c.	205	"	225 "	
Coarse sand, gravel and some cobbles, bluish white	225	"	245 "	
Very clayey sand, yellowish	245	"	260 "	
Dark gray micaceous rock, soft	260	"	290 "	
Dark gray micaceous rock, hard	290	"	450 "	

The stratigraphical position and the lithological character of all the beds below the depth of 50 feet to the top of the micaceous gneiss at 260 feet, clearly shows that they belong to the plastic clays and interbedded gravels that form the basal beds of the Raritan division of the Cretaceous series in New Jersey. To the

writer it seems probable that the heavy cobblestone gravels at 150 and 200 feet represent that division of the Cretaceous known in Maryland and Virginia as the Potomac.

Water horizons were found in the Cretaceous gravels and sands which are the equivalent of horizons used for water-supply in southeastern Philadelphia, and near the Delaware river in the adjacent parts of New Jersey. These, however, were not utilized, the desire being to develop a deep rock well.

It may be noticed that the depth to rock is 260 feet, and that, about 3½ miles W.S.W., in the well reported below on Hog Island, the depth thereto is but 206 feet.

This well is not yet completed, and the boring is still being continued in the micaceous rock belt of Southeastern Pennsylvania.

BORED WELL ON HOG ISLAND, DELAWARE RIVER.

Depth to gneiss	208 feet.
Depth in gneiss	248 "
Total depth	456 "

About the year 1885 a well was bored on the property of E. N. Black, on Black's, or Hog Island, on the Pennsylvania side of the Delaware river, below the mouth of the Schuylkill, and but a short distance south of Fort Mifflin. This island is now separated from the mainland by a narrow and shallow, unnavigable channel, which during the Revolutionary War was large enough to permit vessels to enter; and, in fact, two British war vessels did then enter and remain for a considerable time. Since then the Delaware's main channel has deepened on the New Jersey side, and the old back channel has largely filled up with alluvium.

Incidentally, in the course of a communication upon another subject, by Aubrey H. Smith, before the Academy of Natural Sciences, of Philadelphia, the record of this well was introduced. We copy the same from the Academy's proceedings for 1886, page 254, with the addition on the right of the present author's interpretation of its geology:

Blue alluvium	45 feet	= 45 feet.	Recent.
Sand	1 "	= 46 "	
Blue alluvium	33 "	= 79 "	Age?
Gravel	6 "	= 85 "	
White clay	2 "	= 87 "	Cretaceous. = Plastic clay series.
Beach sand	47 "	= 134 "	
Gravel	10 "	= 144 "	
Clay	3 "	= 147 "	
Red gravel	6 "	= 153 "	
White gravel and sand	17 "	= 170 "	
Beach sand and gravel	38 "	= 208 "	
Decomposed gneiss (mica)	20 "	= 228 "	
Gneiss rock	228 "	= 456 "	

The writer was present at the time the communicatio nwas made, and calls to mind especially the fact that the gravels from the lower part of the unconsolidated strata contained large pebbles, some of which were the size of hens' eggs and larger. In view of the fact now known, that such gravels occur in well-borings in Cretaceous beds along the river to the northward, both in Philadelphia and in Camden and vicinity, we confidently refer all below the depth of 87 feet to that age, and it may be that a considerable portion between 46 and 87 feet should be included. A well at the Philadelphia Navy-yard, on League Island, near by, on the north, entered the Cretaceous clays at about 50 feet. (See preceding record.)

Whether the sample of the borings under consideration are still preserved is not known, but it would be desirable to verify the character of the second, so-called "blue alluvium," of the record. A stratum that could be so designated has not been reported at the navy-yard. If a true alluvium, it would have an interesting bearing upon the history of the river.

ARTESIAN WELLS AT JORDANTOWN, FOR THE MERCHANTVILLE WATER COMPANY.

Elevation, 10 feet or less; diameter, 6 inches; depth, 124 to to 141 feet. Flow of each well, 100 gallons a minute.

Water horizons, { 58 to 78 feet not used.
120 to 140 feet utilized.

In the early summer, four artesian wells were put down for the Merchantville Water Company, at their pumping-station, on the west side of the south branch of the Pensauken, and near Jordanville.

These wells are situated on the meadows or level flood plain of a small tributary of the South Branch, the surface being but a few feet above tide-water. Kisner & Bennett, who sank the wells, have kindly furnished records and data respecting them, which we incorporate below. Specimens of the strata, also, were furnished.

The wells are arranged on an S-shaped line, at intervals of 125 feet. Their depths are as follows: No. 1, 128 feet; No. 2, 129 feet; No. 3, 124 feet, and No. 4, 141 feet. The casing of each well is six inches in diameter, and each is finished at the bottom with a 4½-inch double strainer, 20 feet long.

Each well overflows at the surface, at the rate of 100 gallons per minute, and each was tested by pumping to the capacity of the pump employed, 200 gallons per minute, without apparently diminishing the supply.

Two water-bearing sands were found—the higher one is a somewhat whitish sand, between the depths of 58 and 78 feet, from which the water was somewhat irony, and for this reason was cased off—the lower one was utilized and is in a yellowish sand mixed with coarse pebbles the size of peas; the top of this horizon was met with at the depth of about 120 feet and was about 20 feet in thickness. Well No. 4 reached the base of this sand, where it was found to rest on white clay; neither of the other wells penetrated to its base. The water is clear and palatable and free from irony or other unpleasant taste. It is said an analysis has been made, the result of which is highly satisfactory. The water will rise about five feet above the surface when an additional length of casing is added to the top. Inasmuch as the water in the wells bored north of Delair for the supply of the city of Camden rises only to about tide level, and as the water in the wells now under consideration clearly rises to a greater height, the writer deems it probable the horizon of the latter wells is higher stratigraphically than either of the three horizons noted in this report respecting the former wells.

Geological Notes.

The banks of the Pensauken rise rather steeply from the location of these wells to about forty feet above tide, and thence rise towards Merchantville very gradually to about eighty feet. The strata exhibited in the surface bed belong to the Pensauken formation. Both the usual phases are exhibited, viz.: The underlying fine sand and the overlying gravel. The clay marls, seen at and above tide-level near Maple Shade and, also, at an elevation of about four feet at Merchantville, is wanting in these well-borings. This division of the Cretaceous was probably eroded and carried away before the deposition of the Pensauken over this location. After penetrating a few feet of recent alluvium, constituting quite recent deposits, these wells are entirely within the plastic clay series, *i. e.*, the Raritan division of the Cretaceous.

BORED WELL NEAR MERCHANTVILLE, ON THE FARM OF JAMES A. EAGLE.

Elevation, 50 feet; depth, 130 feet. Water rises within 45 feet of the surface.

Some years since, Caleb Risley put down a well at the above locality to the depth of 130 feet, of which he furnishes from memory the following record:

5 feet	surface soil		5 feet
40 "	mud and clay	5 feet to	45 "
13 "	gravel	45 " "	68 "
12 "	clay	68 " "	80 "
12 "	sand	80 " "	92 "
48 "	alternations of sand and clay and irony crusts	92 " "	130 "

The water from this well is quite irony, and comes from within the clay marls which seldom furnish a good quality of water. Had this well been made about 100 feet deeper it would probably have reached a satisfactory supply from the sands recently opened by the Merchantville water-plant at Jordantown, or, if continued still deeper, there would have been found the heavy gravel horizons supplying wells with good water at Delair, Stockton and Gloucester. The sources of supply at Jordantown, Delair, etc., are within the plastic clays which are free from the glauconitic green sand.

BORED WELL NEAR COLESTOWN ON THE FARM OF JOHN F. STARR.

Depth, 251 feet.

Some years since a well was bored on the farm of John F. Starr, near Colestown, and about two and a half miles southwest of Merchantville station.

From a series of samples preserved by J. F. Starr at his office in the First National Bank of Camden, the subjoined record has been prepared:

Specimens. Depths as marked.	
At 8 feet, brown clay	Clay marls.
" 10 " " "	
" 12 " black "	
" 24 " " "	
" 31 " " "	
" 33 " " "	
Greensand marl specimen, depth not learned.	
At 111 feet, reddish brown clay	Cretaceous plastic clays.
" 160 to 170 feet, whitish clay	
" 180 feet, drab-colored clay	
" 200 " fine red sand	
" 251 " red clay	

BORED WELL AT FELLOWSHIP, NEAR MOORESTOWN.

Elevation, 50 feet; diameter, 5 inches; depth, 275 feet.

A well was noted, in the annual report for 1889, as having been put down on the farm of J. G. Williams, north of Fellowship, to the depth of 260 feet. As there has recently been received from Richard Houseman, who assisted in the boring, a more complete record than was then published, and as the well has lately been deepened by Geo. H. Orcutt, who put in a strainer point to the depth of 275 feet and kindly furnished additional information, we again report this well.

Stated more correctly than in the former reports, this well is located about three-fourths of a mile north of Fellowship on the road to Wilson's station, and nearly two miles south of Moorestown station. The record which follows is a compilation of information received from J. G. Williams, R. Houseman and Geo. H. Orcutt, and has been verified by a visit to the locality and an inspection of some specimens of the borings that had been preserved.

Surface sand, &c.	19 feet	= 19 feet.		
Black clay	55 "	= 74 "	Clay marls.	Cretaceous.
Sand	47 "	= 121 "		
Green marl	8 "	= 129 "		
Sand and coarse white gravel, with lignite	51 "	= 180 "		
White clay and gravel mixed	75 "	= 255 "	Plastic clays.	
Fine white sand, with water	20 "	= 275 "		

The water horizon of this well is in the upper part of the plastic clay series, and is somewhat higher than the horizons furnishing wells at Maple Shade, Delair, Pavonia and Gloucester, and probably also at Jordantown.

BORED WELL TWO MILES SOUTH OF MOUNT EPHRAIM.

Elevation, 60 feet; depth, 134 feet; water rises within 44 feet of the surface.

Some years since, a well was put down for Joseph Haines, on his farm, on the road from Mount Ephraim to Chew's Landing, nearly two miles from the former place. The elevation of the ground is 60 feet. Joseph Haines informs us that after passing through a few feet of surface gravel and about 12 feet of marl, the boring was continued in whitish sand, &c., to the depth of 134 feet, when water was found that rose 90 feet in the tubing. At this depth, the well was completed, and the water has proved satisfactory.

The horizon is the same as that supplying wells at Woodbury, Mantua and Wenonah (Water Works).

BORED WELLS AT WASHINGTON PARK.

No. 1—Elevation, 25 feet; depth, 82 feet. No. 2—Elevation, 25 feet; depth, 92 feet. No. 3—Elevation, 25 feet; depth, 290 feet. No. 3 unfinished.

Leach Brothers report that previously to this year there had been bored at Washington Park, on the Delaware, between Gloucester and Red Bank, two wells to the depth, respectively, of 82 and 92 feet, both of which furnished water slightly irony, which rises about to tide level. They further report that early this year they prospected the well with the depth 92 feet to the depth of 290 feet. The record of strata furnished by the contractors is as follows:

Yellow sand	Surface to 15 feet		
Blue clay	15 feet to 22 "	Clay marls.	Cretaceous.
Blue sand and gravel alternating	22 " " 140 "		
Clay mixed with heavy cobblestone	140 " " 147 "	Plastic clays.	
Red clay with brown gravel streaks	147 " " 182 "		
Sand rock	198 " " 200 "		
Fine sand with considerable lignite	200 " " 210 "		
Alternation of sand and white and red clay	210 " " 290 "		

Hard crust a few inches thick, with fine gravel below.

The transition from the clay marl to the plastic clay series probably occurs at the depth of about 140 feet. Wells Nos. 1 and 2 are evidently furnished with water from sands within but near the base of the clay marls. The excellent water horizons further down within the plastic clays that are now supplying water to Gloucester, Stockton, Delair, Merchantville and Maple Shade should be expected but a short distance below the depth so far reached by the last boring.

BORED WELL ONE MILE SOUTH OF WOODBURY.

Elevation, 20 feet; depth, 130 feet.

Caleb Risley & Son have bored a well at the toll-gate, one mile south of Woodbury, on the turnpike leading from that place to Mantua. The depth reached was 130 feet, water being obtained in a bluish-grey sand toward the base of the clay marls. The boring was commenced in the bottom of a dug well with a depth of 27 feet. The black-clay marls were encountered at the depth of 45 feet, and continued interstratified with sand seams to about the depth of 117 feet.

Fossil shells, not, however, identifiable, being much broken by the drill, were found at the depths of 45, 55 and 108 feet. The water from this well does not become clear. It will probably be deepened twenty to thirty feet, when the clear, clean, coarse, bluish-white gravel found in the bottom of the well at Mantua will most likely be met with. Both wells reach the top of the group of water horizons at the base of the clay marls.

BORED WELL AT THOROFARE.

Elevation, 20 feet; diameter, 2½ inches; depth, 35 feet.

Caleb Risley & Son report a 2½-inch well bored by them at the residence of Lewis A. Wilkins, Thorofare, as follows:

Surface soil			5	feet.
Whitish quicksand	5 feet	to	13	feet.
Black clay	13	"	30	"
White coarse gravel and water	30	"	35	"

The water from the well is irony, but is used for the stock. It comes from the sands within the clay marls. The location is directly opposite, on the other side of the road, from the well reported at DeHart's wheelwright shop (page 123).

BORED-WELL AT THOROFARE.

Elevation, 20 feet; diameter, 3 inches; depth, 146 feet.

I. Haines & Bro., have also bored a well at the residence and store of Lewis A. Wilkins and in close proximity to the well already reported above. They have courteously furnished a full series of the borings, from which we clearly make the following record:

Soil			3	feet.	
Black clay	3 feet	to	20	"	Clay Marls—Cretaceous.
Brownish sand	20	"	27	"	
Yellowish sand, with water (water horizon of previous well)	27	"	37	"	
(*a*) Gray sand, not so yellow	37	"	65	"	
Whitish sand	65	"	75	"	
(*b*) Gray sand, same color as *a*	75	"	94	"	
Greenish-yellow sand	94	"	95	"	
Bluish-gray sand and gravel, with water	95	"	100	"	
Bluish-gray coarse sand and gravel, with large pebbles	100	"	110	"	
Bluish-gray coarse sand and gravel, with large pebbles	110	"	120	"	
Bluish-gray coarse sand and gravel, with large pebbles	120	"	132	"	
Darker gray coarse sand and gravel, with abundance of lignite	132	"	140	"	
Dark-gray coarse sand and gravel, with water	140	"	146	"	
Dark-gray sand, finer; dark clay	146	"	152	"	

Lignite, besides being so abundant at the depth of 135 to 140 feet as to almost constitnte a lignite stratum, was also noticeably present at the depths of 70 and 90 feet. This well, while prospected to the depth of 152 feet, was finished at the depth of 146 feet.

The water horizon reached by this well is the equivalent of that furnishing wells at Mickleton, Auburn, Magnolia, Wenonah (hotel) and Sewell. This horizon is in the bluish-gray gravels and sands near the base of the clay marl series.

BORED WELL AT THOROFARE, N. J.

Elevation, 20 feet; diameter, 2½ inches; depth, 67 feet. Water rises within 18 feet of the surface.

Seth Roberts reports a well bored by him at DeHart's wheelwright shop, in Thorofare, to a depth of 67 feet of which he furnishes the subjoined record:

Commenced in the bottom of a dug well	10 feet.	
8 feet black clay	10 to 18 feet.	Clay marl. Cretaceous.
30 feet blue-white fine sand	18 to 48 feet.	
19 feet coarse sand and gravel	48 to 67 feet.	

The water from this well is somewhat irony—it comes from the sands within the clay marls.

BORED WELL ONE MILE WEST OF THOROFARE.

Elevation, 15 feet; depth, 60 feet.

Caleb Risley & Son furnish the following record of a well bored by them on the farm of William Mullin, on the road from Thorofare to Paulsboro, and about one mile southwest of the first-named place.

18 feet yellow clay and sand, to	18 feet.	
30 " black clay	18 feet to 48 "	Clay marls. Cretaceous.
12 " heavy gravel, with water	48 " 60 "	

The water comes from the sands and gravels at the base of the clay marls.

BORED WELL TWO MILES EAST-SOUTHEAST OF PAULSBORO.

Elevation, 50 feet; diameter, 4 inches; depth, 114 feet.

There is a bored well at the residence of Walter Mills, on the road leading from Paulsboro to the Woodbury and Swedesboro turnpike, and about two miles slightly east of southeast from the first-named town. It has a depth of 114 feet, and is upon ground having an elevation of about 50 feet. After passing through some five feet of surface gravels and sands, about eighty feet of the black clay marl was penetrated. Water, not irony, as in some other bored wells in the neighborhood, was found in a gravel deposit at the bottom. Most of the above information was obtained from Caleb Risley & Son, who bored the well.

BORED WELLS IN PAULSBORO.

Depths, 30 to 60 feet.

Seth Roberts states that he has bored a number of wells in Paulsboro to depths varying from 30 to 60 feet. He says the borings pass through variations in sands, and clays reddish, yellowish and whitish in color. In one well one foot of red clay is reported at the depth of 32 to 33 feet and two feet of white clay at 45 to 47 feet. He observed "charcoal" in one well at 28 to 30 feet, and in another at 38 to 40 feet. The water horizon at the bottom is a coarse gravel, which must be within the plastic clays, as none of the black clay occurs here that has been found in the borings at and near Thorofare and which belong to the clay marls. The black clay is also absent at Billingsport.

BORED WELL AT BILLINGSPORT.

Diameter, 3 inches; depth, 67 feet; water rises to the surface.

Seth Roberts informs that he bored a three-inch well at a boathouse on the Delaware river bank at Billingsport, south of the mouth of Mantua creek, and furnishes the subjoined record:

Yellow sand, gravel and clay to			12	feet.
Alternations of quicksand and white clay	12	feet to	50	"
Sand and gravel, with some pebbles large as goose eggs	50	"	55	"
Pure, firm, white potter's clay	55	"	61	"
White quicksand, with water	61	"	63	"
Hard rock	63	"	67	"

The water rises to the surface, but does not overflow; it comes from the water horizons within the plastic clays.

BORING AT CLARKSBORO.

Elevation, 70 feet; depth, 90 feet.

A boring was prospected at a point about one-half mile southeast of Clarksboro station to the depth of 90 feet, where the black clay characteristic of the clay marls was met with and the work discontinued. This notice is inserted because the occurrence of the clay marl marks a definite geological horizon, and may become useful in the future in the construction of vertical sections of the region.

BORED WELL AT MICKLETON.

Elevation, 70 feet; diameter, 3 inches; depth, 238 feet; water rises within 61 feet of the surface.

Late in the year 1895, a well was put down at the residence of Jeremiah Haines, in Mickleton, on the railroad to Swedesboro and Salem. The drilling was done by J. Haines & Bro., artesian well contractors, of which firm Jeremiah Haines is a copartner.

From information verbally obtained, and from a set of the borings from below the depth of 100 feet, to the bottom, the following record has been compiled.

15 feet	surface soil, &c.			15 feet.
45 "	marl	15	to	60 "
5 "	black sand	60	"	65 "
	Mud		at	100 "
	Gravel		"	150 "
	Gravel		"	165 "
	Dark-blue, fine clay, sticky, like putty		"	180 "
	Gravel, with *good water*	228 feet	to	238 "

This water horizon is identical with that reached by wells at or near Auburn, at the hotel at Wenonah and at Sewell. The wells at the water-works at Wenonah and at George Horner's, near Harrisonville, stop stratigraphically about 60 feet higher and probably draw from the upper portion of this horizon.

UNFINISHED BORING AT SWEDESBORO.

Elevation, 60 feet; diameter, 3 inches; depth, 172 feet. Probable depth to water horizons, 190 to 250 feet.

The record of an uncompleted boring at the residence of Wm. Longacre, in Swedesboro, is reported thus:

Surface soil &c	10 feet.	
Black clay to	172 "	=Clay marls.

From the inspection of a vertical section of this region, constructed from well data in hand, it seems probable that between the depths of 190 and 250 feet from the surface the same group of water horizons occur that supplies the wells at Mickleton, Auburn, Wenonah, Sewell and George Horner's near Harrisonville.

BORED WELL ONE MILE NORTH OF HARRISONVILLE.

Elevation, 120 feet; depth, 402 feet. Water rises within 114 feet of the surface.

Early in the year J. Haines & Bro., contractors, sunk a well upon the farm of George Horner, nearly one mile north of the mill at Harrisonville. They furnished a series of the borings and imparted verbally some information from which the record below is compiled:

Orange-yellow, loamy sand	17	to	40	feet.
Interval, specimen wanting	40	"	80	"
Light green marl	80	"	100	"
Green sand with fragments of shell; numerous *foraminifera* and *sea-urchin* spines	100	"	110	"
Yellowish green marly clay; fragments of shell and *Belemnites* at about 125 feet	110	"	165	"
Interval, specimen missing	165	"	230	"
Clayey marl	230	"	260	"
Clayey marl at			360	"
Stiff marly clay at			372	"
Gray sand, yielding water, at			402	"

The water-supply of this well comes from the water-yielding sand near the base of the clay marls. It is probably equivalent to that supplying the water company's well at Wenonah, and which does not draw from as low a water horizon as that which supplies the well at the Wenonah Hotel. F. J. Anspach's well at Sewell

found coarse, heavy gravels, water yielding, between the depth of 342 and 420 feet. The bottom of this well (402 feet) is probably stratigraphically equivalent to the depth of 342 feet at the top of water-yielding horizon at Sewell.

This group of water horizons, which, as above stated, is interbedded at Sewell between the depths of 342 and 420 feet, has been also tapped by wells at the following localities:

			Elevation of Surface.
At Mickleton, with a depth of	238 feet	=	70 feet
At Auburn, with a depth of	301 "	=	100 "
At Wenonah Water-Works, with a depth of	196 "	=	10 "
At Wenonah Hotel, with a depth of	341 "	=	70 "
At Woodstown, with a depth of	339 "	=	17 "

Though this horizon was found at Woodstown at the depth of 339 feet it was not utilized, because a higher and equally satisfactory water-yielding stratum exists there, to which a number of wells were sunk. These were noted in the report for the year 1892, page 301.

BORED WELL NEAR AUBURN, N. J.

Elevation, 100 feet; diameter, 3 inches; depth, 296 feet. Water rises to within 100 feet of the surface.

Early in the summer J. Haines & Bro. finished a well on the farm of Benjamin Cheesman upon the road leading from Woodstown to Auburn, about one mile southeast of the latter place. This well is upon the 100-foot contour line on the northwest slope of a 133-foot hill which rises quite abruptly above the 110-foot level.

The contractors courteously furnished a full set of borings, from a careful examination of which the following record has been made:

2 feet.	Surface soil		2 feet.	
4 "	Clay and gravel	2 feet to	6 "	
8 "	Orange-colored sand, called moulding sand	6 "	14 "	Beacon Hill.
1 "	"Bullhead" bowlders,* on green clay marl	14 "	15 "	Beacon Hill.

*So much difficulty was experienced in getting the case through these bowlders which are of quartzite, that one pit was dug down to them and a small one removed, which was one foot in diameter, and was closely packed between three larger ones, apparently several feet in length. The casing was then sunk through the opening thus made.

10	"	Light-olive green sand marl..	15	"	25	"		
10	"	Clay, gravel and greensand mixed, dark olive-green color	25	"	35	"		
10	"	Lighter olive greensand, consisting of whitish quartz grain and glauconitic grains mixed..................	35	"	45	"	Lower marl?	
50	"	Reddish-yellow quartzose sand, with a few greensand grains....................	45	"	95	"		
20	"	Sandy, marly clay, a few greensand grains............	95	"	115	"		
10	"	Reddish-yellow sand, same as above.........................	115	"	125	"		
20	"	Olive-green clay and sand, white and red stained quartz grains and some glauconite grains.............	125	"	145	"		Cretaceous.
10	"	Gravelly conglomeritic mixture of whitish quartz grains and dark-blue mineral grains, consisting of *vivianite;* teeth and vertebra of shark...............	145	"	155	"	Clay marls.	
25		White sand and running black mud.....................	155	"	180	"		
87	"	Dark clay marl, micaceous...	180	"	267	"		
23	"	Medium sand, very slightly olive in color.................	267	"	290	"		
10	"	Coarser sand, bluish-white in color, with water.........	290	"	300	"		
1	"	Red and white mottled clay, colored water blood-red...	300	"	301	"	Plastic clay.	

BORED WELL AT PITMAN GROVE.

Elevation, 110 feet; diameter, 3 inches; depth, 190 feet. Water rises within 18 feet of the surface. Also notes on more shallow wells within the grove.

In the early summer J. Haines & Bro. bored a well within the Methodist camp-meeting grounds at Pitman Grove, N. J., at a point about one-third of a mile southwest of the railroad station The well is upon nearly the lowest ground within the area, and at the western edge of the grove; the elevation, according to the survey map, being 110 feet.

From a series of specimens of borings, which were carefully saved and courteously furnished by the contractors, the record here inserted has been made.

10 feet.	Surface soil, &c., say		10 feet.		
10 "	Orange-colored sand	10 feet to	20 "		
10 "	Orange-colored sandy clay	20 "	30 "		
30 "	Orange-colored sand, some clay	30 "	60 "	Beacon Hill.	
10 "	Orange-colored sandy clay	60 "	70 "		
10 "	Dark clay, nearly black	70 "	80 "	Miocene (?)	
20 "	Bryozoan limesand, *Nodosaria*, *Echinus* spines and *Bryozoa*	80 "	100 "		
10 "	Greensand marl, with *Nodosaria* (foraminifera) and fragments of shell, probably *Terebratula*	100 "	110 "		
10 "	Greensand marl, less shell	110 "	120 "	Middle and	
10 "	Clayey greensand	120 "	130 "	Lower Marl.	Cretaceous.
10 "	Clayey sand	130 "	140 "		
10 "	Clayey marl, *Belemnites* and ponderous shells	140 "	150 "		
30 "	Yellowish sand, with some clay, *Belemnites* and fragments of mollusk, the latter not identifiable	150 "	180 "		
10 "	Medium-coarse, clear sand, with water	180 "	190 "		

The supply comes from the Marlton-Medford water horizon at the base of the marl series.

SHALLOW BORED WELLS AT PITMAN GROVE.

The preceding record harmonizes with notes in the Annual Report for 1891, page 220, respecting eight other wells within the Grove, most of which are supplied from the Beacon Hill sands of the above section and were, according to difference in elevation, from 60 to 80 feet deep. One well, however, it is there stated, was prospected to the depth of 130 feet to conglomerate, marl being found at the depth of 96 feet.

UNFINISHED BORING AT SWEDESBORO.

Elevation, 60 feet; diameter, 3 inches; depth, 172 feet. Probable depth to water horizons, 190 to 250 feet.

The record of an uncompleted boring at the residence of Wm. Longacre, in Swedesboro, is reported thus:

Surface soil &c	10 feet.	
Black clay to	172 "	=Clay marls.

From the inspection of a vertical section of this region, constructed from well data in hand, it seems probable that between the depths of 190 and 250 feet from the surface the same group of water horizons occur that supplies the wells at Mickleton, Auburn, Wenonah, Sewell and George Horner's near Harrisonville.

BORED WELL ONE MILE NORTH OF HARRISONVILLE.

Elevation, 120 feet; depth, 402 feet. Water rises within 114 feet of the surface.

Early in the year J. Haines & Bro., contractors, sunk a well upon the farm of George Horner, nearly one mile north of the mill at Harrisonville. They furnished a series of the borings and imparted verbally some information from which the record below is compiled:

Orange-yellow, loamy sand	17	to	40 feet.
Interval, specimen wanting	40	"	80 "
Light green marl	80	"	100 "
Green sand with fragments of shell; numerous *foraminifera* and *sea-urchin* spines	100	"	110 "
Yellowish green marly clay; fragments of shell and *Belemnites* at about 125 feet	110	"	165 "
Interval, specimen missing	165	"	230 "
Clayey marl	230	"	260 "
Clayey marl at			360 "
Stiff marly clay at			372 "
Gray sand, yielding water, at			402 "

The water-supply of this well comes from the water-yielding sand near the base of the clay marls. It is probably equivalent to that supplying the water company's well at Wenonah, and which does not draw from as low a water horizon as that which supplies the well at the Wenonah Hotel. F. J. Anspach's well at Sewell

found coarse, heavy gravels, water yielding, between the depth of 342 and 420 feet. The bottom of this well (402 feet) is probably stratigraphically equivalent to the depth of 342 feet at the top of water-yielding horizon at Sewell.

This group of water horizons, which, as above stated, is interbedded at Sewell between the depths of 342 and 420 feet, has been also tapped by wells at the following localities:

			Elevation of Surface.
At Mickleton, with a depth of	238 feet	=	70 feet
At Auburn, with a depth of	301 "	=	100 "
At Wenonah Water-Works, with a depth of	196 "	=	10 "
At Wenonah Hotel, with a depth of	341 "	=	70 "
At Woodstown, with a depth of	339 "	=	17 "

Though this horizon was found at Woodstown at the depth of 339 feet it was not utilized, because a higher and equally satisfactory water-yielding stratum exists there, to which a number of wells were sunk. These were noted in the report for the year 1892, page 301.

BORED WELL NEAR AUBURN, N. J.

Elevation, 100 feet; diameter, 3 inches; depth, 296 feet. Water rises to within 100 feet of the surface.

Early in the summer J. Haines & Bro. finished a well on the farm of Benjamin Cheesman upon the road leading from Woodstown to Auburn, about one mile southeast of the latter place. This well is upon the 100-foot contour line on the northwest slope of a 133-foot hill which rises quite abruptly above the 110-foot level.

The contractors courteously furnished a full set of borings, from a careful examination of which the following record has been made:

2 feet.	Surface soil		2 feet.	
4 "	Clay and gravel	2 feet to	6 "	
8 "	Orange-colored sand, called moulding sand	6 "	14 "	Beacon Hill.
1 "	"Bullhead" bowlders,* on green clay marl	14 "	15 "	

* So much difficulty was experienced in getting the case through these bowlders which are of quartzite, that one pit was dug down to them and a small one removed, which was one foot in diameter, and was closely packed between three larger ones, apparently several feet in length. The casing was then sunk through the opening thus made.

UNFINISHED BORING AT SWEDESBORO.

Elevation, 60 feet; diameter, 3 inches; depth, 172 feet. Probable depth to water horizons, 190 to 250 feet.

The record of an uncompleted boring at the residence of Wm. Longacre, in Swedesboro, is reported thus:

Surface soil &c.	10 feet.
Black clay to	172 " =Clay marls.

From the inspection of a vertical section of this region, constructed from well data in hand, it seems probable that between the depths of 190 and 250 feet from the surface the same group of water horizons occur that supplies the wells at Mickleton, Auburn, Wenonah, Sewell and George Horner's near Harrisonville.

BORED WELL ONE MILE NORTH OF HARRISONVILLE.

Elevation, 120 feet; depth, 402 feet. Water rises within 114 feet of the surface.

Early in the year J. Haines & Bro., contractors, sunk a well upon the farm of George Horner, nearly one mile north of the mill at Harrisonville. They furnished a series of the borings and imparted verbally some information from which the record below is compiled:

Orange-yellow, loamy sand	17 to 40 feet.
Interval, specimen wanting	40 " 80 "
Light green marl	80 " 100 "
Green sand with fragments of shell; numerous *foraminifera* and *sea-urchin* spines	100 " 110 "
Yellowish green marly clay; fragments of shell and *Belemnites* at about 125 feet	110 " 165 "
Interval, specimen missing	165 " 230 "
Clayey marl	230 " 260 "
Clayey marl at	360 "
Stiff marly clay at	372 "
Gray sand, yielding water, at	402 "

The water-supply of this well comes from the water-yielding sand near the base of the clay marls. It is probably equivalent to that supplying the water company's well at Wenonah, and which does not draw from as low a water horizon as that which supplies the well at the Wenonah Hotel. F. J. Anspach's well at Sewell

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At Wenonah Water-Works, with a depth of	196 "	=	10 "
At Wenonah Hotel, with a depth of	341 "	=	70 "
At Woodstown, with a depth of	339 "	=	17 "

Though this horizon was found at Woodstown at the depth of 339 feet it was not utilized, because a higher and equally satisfactory water-yielding stratum exists there, to which a number of wells were sunk. These were noted in the report for the year 1892, page 301.

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Elevation, 100 feet; diameter, 3 inches; depth, 296 feet. Water rises to within 100 feet of the surface.

Early in the summer J. Haines & Bro. finished a well on the farm of Benjamin Cheesman upon the road leading from Woodstown to Auburn, about one mile southeast of the latter place. This well is upon the 100-foot contour line on the northwest slope of a 133-foot hill which rises quite abruptly above the 110-foot level.

The contractors courteously furnished a full set of borings, from a careful examination of which the following record has been made:

2 feet.	Surface soil		2 feet.	
4 "	Clay and gravel	2 feet to	6 "	
8 "	Orange-colored sand, called moulding sand	6 "	14 "	Beacon Hill.
1 "	"Bullhead" bowlders,* on green clay marl	14 "	15 "	Beacon Hill.

*So much difficulty was experienced in getting the case through these bowlders which are of quartzite, that one pit was dug down to them and a small one removed, which was one foot in diameter, and was closely packed between three larger ones, apparently several feet in length. The casing was then sunk through the opening thus made.

DUG WELLS AT PITMAN GROVE.

It may here be noted that there are also within the Grove two dug wells, each with a depth of about 20 feet. These are considered as natural springs by those in charge. The drinking-water for a number of restaurants under one management in Philadelphia is daily furnished from one of these wells.

BORED WELLS AT BARNSBORO.

Elevation, 100 feet; diameter, 3 inches; depths, 110 and 170 feet. Water rises within 54 feet of the surface.

Early in the year J. Haines & Bro. bored two wells for Dilks Brothers, about one-half mile southwest of the five points formed by the cross-roads in Barnsboro. These wells are on ground of nearly the same level, and having an elevation of about 100 feet. Both wells found water and were finished at a depth of 110 feet, though one was prospected beyond to the depth of 170 feet. From the deeper boring a complete series of specimens was kindly furnished by the contractors. The section revealed by these specimens is as follows:

	Surface soil, say		5 feet	
34 feet	Orange col'd sand (no specimen)	5 to	15 "	Beacon Hill.
	" " "	15 "	39 "	
5 "	Dark clay, no greensand nor other micro-organisms	35 "	40 "	Miocene.
20 "	Light green marl	40 "	60 "	Lower Marl.
25 "	Rusty green marl, lower 10 feet with coarser quartzose sand grains	60 "	85 "	
	At 60 to 65 feet fragment of a small oyster, not identified.			
70 "	Gray sand, with a few clay seams	85 "	155 "	Clay Marls.
	Belemnites at 95 feet and at 105 feet.			
	Abundance of *water* at 110 feet.			
15 "	Muddy, sandy clay	155 "	170 "	

The gray sand above noted, from which both these wells draw their supply, is the same sand that furnishes water to the wells at Quinton and Woodstown, and to most of the wells in the Marlton and Medford region.

From a series of specimens of borings, which were carefully saved and courteously furnished by the contractors, the record here inserted has been made.

10 feet.	Surface soil, &c., say			10 feet.		
10 "	Orange-colored sand	10 feet to		20 "	Beacon Hill. Miocene (?)	
10 "	Orange-colored sandy clay	20	"	30 "		
30 "	Orange-colored sand, some clay	30	"	60 "		
10 "	Orange-colored sandy clay	60	"	70 "		
10 "	Dark clay, nearly black	70	"	80 "		
20 "	Bryozoan limesand, *Nodosaria*, *Echinus* spines and *Bryozoa*	80	"	100 "	Middle and Lower Marl.	Cretaceous.
10 "	Greensand marl, with *Nodosaria* (foraminifera) and fragments of shell, probably *Terebratula*	100	"	110 "		
10 "	Greensand marl, less shell	110	"	120 "		
10 "	Clayey greensand	120	"	130 "		
10 "	Clayey sand	130	"	140 "		
10 "	Clayey marl, *Belemnites* and ponderous shells	140	"	150 "		
30 "	Yellowish sand, with some clay, *Belemnites* and fragments of mollusk, the latter not identifiable	150	"	180 "		
10 "	Medium-coarse, clear sand, with water	180	"	190 "		

The supply comes from the Marlton-Medford water horizon at the base of the marl series.

SHALLOW BORED WELLS AT PITMAN GROVE.

The preceding record harmonizes with notes in the Annual Report for 1891, page 220, respecting eight other wells within the Grove, most of which are supplied from the Beacon Hill sands of the above section and were, according to difference in elevation, from 60 to 80 feet deep. One well, however, it is there stated, was prospected to the depth of 130 feet to conglomerate, marl being found at the depth of 96 feet.

estimate similarly based on the rate of dip would indicate the depth at Clayton to the same water-yielding horizon at about 400 feet.

BORED WELL AT MANTUA.

Elevation, 10 feet; diameter, 3 inches; depth, 195 feet.
Water rises within 10 feet of the surface.

A well has been bored for Job Scott, at Mantua, by Joseph Hebgen, contractor, who has furnished the following account of strata:

Greenish sand and marl		to	110	feet.
Black sand	110	feet to	125	"
Greenish sand	125	"	180	"
White gravel with water	180	"	195	"

We are informed that large molluscan shells (probably *Exogyra*) are found near the surface at the locality of this well and at about the same level or one very slightly higher.

The well is supplied from the same horizon as the wells at Woodbury, Mickleton, Wenonah (Water Works Co.), and near Harrisonville (George Horner's).

BORED WELL AT MAGNOLIA.

Elevation, 94 feet; depth, 330 feet.

In the Annual Report for 1894, page 197, there is a record of a well put down at Magnolia to the depth of 94 feet. During the present year J. Haines & Bro. have drilled a well adjacent thereto to a depth of 330 feet. The record below is compiled from the record of 1894 and from specimens and memoranda respecting the present well, kindly furnished by J. Haines & Bro.:

Soil and yellow clay and sand, surface to			10	feet.
Yellowish gravel, greenish tinge	10	feet to	20	"
Olive-green marl	20	"	23	"
Dark green marl	23	"	30	"
Greenish-gray sand	30	"	56	"
* Hard [stratum] like lime, with shells; these shells had ridges on them, the edges were scalloped	56	"	59	"

* This stratum is from W. R. Kelly's record of a well 91 feet deep, published in the Annual Report for 1894, and is inserted for whatever geological significance they may have.

Greenish-yellow sand; bottom of dug well 70 feet in this...	59 feet	to	74 feet.
*Gray sand and shells, cemented together with a substance like lime; the strata would change about a foot apart.....	74	"	84 "
Very dark gray sand, with water..........	84	"	91 "
Greenish-yellow sand; bottom of former bored well at 91 feet in this..........	91	"	105 "
Marl..........	105	"	205 "
Running sand, mixed with marl..........	205	"	245 "
Marl, hard, sandy..........	245	"	322 "
Sand, with water..........	322	"	330 "

In all the sands described above as yellowish, greenish-yellow or olive-green, there was a greater or less mixture of true greensand or glauconite grains.

BORED WELL AT LAUREL SPRINGS.

Elevation, 70 feet; diameter, 3 inches; depth, 45 feet. Water rises within 10 feet of the surface. Supply from within the Bryozoan lime-sand.

W. R. Kelly courteously saved and furnished a full series of borings from a well put down by him early in the summer at the residence of Jacob Kraus, at Laurel Springs, N. J. This well is upon or nearthe 70-foot contour line of the Survey's topographical map, and is located immediately southwest of the railroad station. The record compiled from the specimens is as follows:

Commenced in the bottom of the cellar at the depth of....3 feet.		Beacon Hill.
Orange-yellow gravel with some heavy pebbles......	3 to 9 "	
Orange-yellow gravel, finer..........	9 " 13 "	
Orange-yellow clayey sand or sandy clay..........	13 " 17 "	Probably Miocene.
Dark clay, brown and yellowish, transitional..........	17 " 20 "	
Dark brown clay..........	20 " 27 "	
Olive colored, clayey greensand..........	27 " 32 "	Cretaceous.
Dark green clay..........	32 " 35 "	
Hard crust..........	35 " 36 "	
Bryozoan lime-sand with water that rises within 10 feet of the surface..........	36 " 45 "	

This well is supplied from the upper portion of the Bryozoan lime-sand.

The Terebratula layer of the Middle Marl bed occurs farther down, at the depth of about 73 feet, as has been ascertained for another well near by, and which we next record.

* This stratum is from W. R. Kelly's record of a well 91 feet deep, published in the Annual Report for 1894.

BORED WELL AT LAUREL SPRINGS HOTEL.

Elevation, 65 feet; depth, 73 feet.

Some years since a well was put down for the use of the Laurel Springs Hotel. This well is upon lower ground than the one just described, and has a depth of 73 feet. A record of this well was not kept, but recently there was obtained from the bottom well-preserved *Terebratula* and *Gryphea* shells of the two species characteristic wherever they occur in this state of the Middle Marl bed, being found next beneath the Bryozoan limesand layer. The well of the next preceding record, as there stated, draws from the upper part of the Bryozoan limesand, while this one probably obtains its supply from below the Middle Marl.

BORED WELL BETWEEN LINDENWOLD AND LAUREL S[illegible]

Elevation, 80 feet; depth, 75 feet.

This well was bored at the residence of E. Z. C[illegible] W. [illegible] Kelly, from whom we learn that the total dep[illegible] 75 feet, and that a supply of wa[illegible] was found [illegible] a loose sand, interbedded in t[illegible] *[illegible]yozoan* li[illegible] which was met with at the d[illegible] 57 feet[illegible] limesand from the bottom, w[illegible] usual [illegible] fossils, were furnished. The [illegible] surface [illegible] the neighborhood occupied th[illegible] 20 feet [illegible] that the same succession of [illegible] were [illegible] recorded in the well at Linde[illegible] which [illegible]

BORED WEL[illegible]

Elevation, 100 feet; diameter, 3 inc[illegible] feet of the surface; supply f[illegible]

In the spring of the presen[illegible] wold, by W. R. Kelly, of that [illegible] Camden and Atlantic railroa[illegible]

Kirkwood. The well is near the 100-foot contour line, or near the top of the 104-foot hill, near to and west of the station. The record is here inserted:

The boring commenced in the bottom of a dug well, at a depth of	21 feet.	Pensauken.
White sand and gravel	21 to 23 "	
Orange-yellow gravel and clayey sand	23 " 43 "	Beacon Hlil.
Fine, orange-yellow sand	43 " 58 "	
Yellow, sandy clay	58 " 61 "	
Dark brown sand	61 " 66 "	Probably Miocene.
Marl, clay and sand, greensand grains	66 " 71 "	Possibly Eocene.
Dark-colored gravel	71 " 78 "	Bryozoan limesand. Cretaceous.
Gravel containing *Bryozoa*, good supply of water	78 " 82 "	

This well is supplied from the porous, sandy layers of the ryozoan limesand that overlies the Middle Marl.

ED WELLS ONE AND THREE-FIFTHS MILES EAST OF CLEMENTON STATION.

No. 1.—Elevation, 150 feet; diameter, 3 inches; depth, 230 feet.
No. 2.—Elevation, 120 feet; diameter, 3 inches; depth, 20 feet.

g the summer W. R. Kelly, of Lindenwold, bored a three-l upon the premises of Mrs. Anna B. Glover, on the lope of the 184-foot hill to the eastward of Clementon. is located upon the 150-foot contour line of the Sur-pographical map, and is along the road leading from on to Berlin. Measured by a direct line upon the map, ant one and three-fifths miles westward from Clementon upon the Reading Railroad Company's route to Atlantic

and carefully-marked series of specimens of the borings ished by W. R. Kelly. The boring was commenced in of a dug well having a depth of 33 feet. The record vs:

To the bottom of dug well		33 feet.	
Fine yellow sand	33 feet to	38 "	Beacon Hill (?)
Fine yellow sandy clay	38 "	39 "	
Medium-coarse yellow sand, with some water	39 "	44 "	
Finer yellow sand, with some water	44 "	59 "	
Fine clayey yellow sand	59 "	69 "	
Fine clayey yellow sand	69 "	74 "	
Fine clayey yellow sand	74 "	84 "	
Dark clayey sand	84 "	99 "	Miocene (?)
Dark clayey sand	99 "	105 "	
Dark-brown sandy clay	105 "	125 "	
No micro-organisms in the last three specimens.			
Greensand marl	125 "	132 "	Upper layer of the Upper Marl bed.
Ash-colored clay	132 "	162 "	Middle or ash-colored layer of the Upper Marl bed.
Ash-colored clay	162 "	189 "	
Greensand marl	189 "	196 "	Lower layer of the Upper Marl bed.
Greensand marl	196 "	203 "	
Limesand, greensand, *Bryozoa*	203 "	208 "	Middle Marl bed.
Greensand and shell, *Terebratula* and *Gryphea*	208 "	213 "	
Greensand	213 "	230 "	

A hard crust or rock occurred at this depth, and the boring was discontinued, and a more shallow well (No. 2), with a depth of only 20 feet, was put down near by on lower ground, the elevation being 120 feet. A supply sufficient for needs was found, though sufficient water did not appear in Well No. 1 at the same level.

Geologically this record is interesting, since it shows the continuation along the line of strike to the southwest of all three divisions of the Upper Marl bed that are met with in many well-borings along the coast in Monmouth county, at Asbury Park and southward. These three layers are an upper greensand, intermediate, ash-colored clay or, as it is sometimes called, ash marl, and a lower greensand. As in Monmouth county, so here the middle ash-colored layer has a considerable thickness.

Stratigraphically all three divisions occur above the Middle Marl bed, whose upper member is a bryozoan limesand or limerock, of which only a thin stratum is exhibited in this boring, although at Quinton it is developed to a thickness of slightly over 100 feet.

BORED WELL AT CROPWELL.

Elevation, 100 feet; diameter, 3 inches; depth, 137 feet.
Water rises within 30 feet of the surface.

W. C. Barr furnishes the following record of a well bored by him on the property of F. G. Lippincott, on the 100-foot hill south of Cropwell station:

Soil		5 feet.
Loam, sand, &c.	35 feet	to 40 "
Gray and black quicksand, changed to red at the bottom	35 "	" 75 "
Black mud	10 "	" 85 "
Chocolate marl with some broken shell and pyrite crust at 127 feet	49 "	" 134 "
Coarse gray sand with water	3 "	" 137 "

The water rises within 30 feet of the surface.

BORED WELLS AT MIDDLETOWN, DEL.

Elevation, 40 (?) feet. Three wells, diameter, 6 inches; depth, 88 feet.
Water rises to within 13 feet of the surface.
One well, diameter, 8 inches; depth, 552 feet.
Water rises to within 34 feet of the surface.
Water horizon at 88 feet.
" " " 475 to 495 feet.
" " " 517 to 534 "
" " " above 552 "

Four wells have been drilled at various times at Middletown, Del., for the Light and Water Commission there. Three of them have a depth of 88 feet, while the other was continued to the depth of 552 feet. The situation of Middletown is such that the deeper of these borings is particularly illustrative of New Jersey geology near the head of Delaware Bay, where we are deficient in well records. For this reason the details respecting these wells are inserted.

From information received from J. W. Jolls, secretary of the Commission; from Geo. J. Kennedy, who put down the deep well to the depth of 479 feet, and from J. H. K. Shanahan, who afterwards continued the same to the depth of 552 feet, and also bored the three more shallow (88 feet) wells, and from knowledge gained from an examination of specimens of the borings kindly furnished by both contractors, the record below has been made.

The more shallow wells, or those with the depth of only 88 feet, probably draw from the same water-bearing sands that are tapped in this State by wells at Quinton and Woodstown, and in the Marlton and Medford region, viz., the sands at the base of the Lower Marl and above the clay marls.

The deep well (552 feet) draws from water-bearing sands within the plastic clays; the water-bearing beds utilized occuring between the depth of 475 and 495 feet, and between the depth of 517 and 534 feet. The well was prospected beyond the last-named depth to another water-yielding sand, not, however, utilized, which was found below 538 feet and above 552 feet. At the latter depth hard rock was encountered. We have not been able to learn whether or not this rock was the gneiss rock that undoubtedly underlies the Atlantic Coastal plain in this region. Very probably, however, it was an interbedded sandstone crust of the Cretaceous. Other water-yielding sands than those utilized are noted in the record which follows:

27 feet.	Surface sands and gravel			27	feet.	Pleistocene.	
45 "	Iron-colored sands, with crusts...	27	feet to	72	"	Marl Series.	Cretaceous.
3 "	Indurated greensand	72	"	75	"		
4 "	Red and yellow sand	75	"	79	"		
	Water-bearing sand at *			90	"	Clay Marls.	
	Greenish sand at			110	"		
	Sand and clay at	110	"	133	"		
7 "	Fine white sand, with *water*	133	"	140	"		
2 "	Black and green sand	140	"	142	"		
4 "	White and yellow sand	142	"	146	"		
24 "	Clay	146	"	170	"		
34 "	Alternations of sands, clays and gravels, *water-bearing* †	170	"	204	"		
20 "	Clay, with three sand seams	204	"	224	"		
92 "	Interval no record, except whitish crust at 275 feet	224	"	318	"		
29 "	Very hard white clay	318	"	347	"		
3 "	Clay, with abundance of *lignite*...	362	"	365	"		
10 "	*Cemented shells* at	390	"	400	"		
	Red clay at			425	"	Plastic Clays.	
	Hard crust, three inches, at			442	"		
20 "	White sand, *water-bearing* ‡	475	"	495	"		
22 "	White and red clay	495	"	517	"		
17 "	White sand, *water-bearing* ‡	517	"	534	"		
4 "	White clay	534	"	538	"		
14 "	Sand, with *water*	538	"	552	"		
	Rock (?) at 552 feet.						

* Water horizon of the 88-foot wells. Water rises within 13 feet of the surface.

† This horizon was not used. Water rises therefrom to within 20 feet of the surface.

‡ Water horizon of the deep well. Water rises within 34 feet of the surface.

From the foregoing and accompanying foot-notes it may be noticed that the water from the lowest horizon does not rise to so high a level as from the two upper horizons. Similar conditions occur at Woodstown on the New Jersey side of the Delaware, where water from the upper horizon rose nearly to the surface, while from the depth of 339 feet it rose only to within 14 feet of the same level, and from the depth of 776 feet to within only 18 feet thereof. These facts at Woodstown were recorded in the report for 1892, page 302 and, also, on the vertical section plate 9, page 202, of the annual report for 1894.

BORED WELL AT NEW CASTLE, DELAWARE.

As we go to press, W. R. Osborne informs us that he has a well now in process of drilling at New Castle, Delaware, for the Wilmington and New Castle Electric railroad. He states that the boring has reached a depth of 160 feet. Broken strata of clays and fine sands have been passed through. Very muddy water occurred at the depths of 85, 100 and 155 feet. The clays were principally either very red or pink. A large amount of charred wood was found on top of the sand at 150 feet. No good water as yet.

BORED WELL TWO MILES SOUTH OF NEW CASTLE, DELAWARE.

Diameter, 2 inches; depth, 111 feet.
The water rises within 14 feet of the surface.

Early in the year a well was bored at Lupton's Brick Works, near the river, about two miles below New Castle and near the range lights of the United States Government at that point. The following record has been courteously furnished by W. R. Osborne, the contractor.

Red clay to		38 feet.	Plastic Clays.	Cretaceous.
White, sandy clay	12 feet	= 50 "		
Blue clay	10 "	= 60 "		
Blue, sandy clay	37 "	= 97 "		
Sand, with *water*	14 "	= 111 "		

We are informed that the water rises within 14 feet of the surface, and that it is good for domestic use and does not scale in the boiler.

BORED WELL NEAR HARE'S CORNERS.

Three miles west of New Castle, Del.
Elevation, 90 feet (?); diameter, 4 inches; depth, 228 feet.
The water rises within 100 feet of the surface.

This well was bored for W. C. Spuance, an attorney of Wilmington, on his farm near Hare's Corners.

The following verbatim record respecting it has been kindly furnished by W. R. Osborne, who put it down. The well is upon the ridge between the Delaware and the Christiana rivers. The location is said to be 90 feet above tide. The water rises in the well to within 100 feet of the surface.

RECORD.

Yellowish clay and sand	25 feet	= 25 feet		
Blue clay	25 "	= 50 "	Plastic Clays.	Cretaceous.
Red clay	5 "	= 55 "		
Yellow sand	5 "	= 60 "		
Iron ore (?), very red water	10 "	= 70 "		
Yellow sand and water	10 "	= 80 "		
White and blue clay	20 "	= 100 "		
Red clay, *water* at the base	75 "	= 175 "		
Blue clay	25 "	= 200 "		
Bluish sand with wood, very black, resembling charcoal	10 "	= 210 "		
This stratum is *water bearing*.				
Red and white clay	10 "	= 220 "		
White sand, with *water*	8 "	= 228 "		

All below the depth of 50 feet in the above record certainly belongs to the Plastic or Raritan clays of New Jersey, and possibly all below the depth of 25 feet.

ARTESIAN WELL AT REEDY ISLAND.

Depth, 574 feet.
Prospected to the depth of 593 feet.
Overflows 20 gallons a minute.

An artesian well was bored late the present year at the United States Quarantine Station, on Reedy Island, in the Delaware river, opposite Port Penn, Delaware, and about seven miles almost directly southwest of Salem, N. J., which place and the

Quarantine station are nearly on the line of strike of the Cretaceous strata. The well has a depth of 574 feet and obtains a supply of excellent water from a white sand entered at the depth of 570 feet. Through the courtesy and co-operation of Dr. A. H. Glennon, surgeon at the station, and of J. H. K. Shanahan, the contractor, a full series of borings has been received from below the depth of 91 feet. After careful examination of these, we make the following record, in which there is also included some information received both from the surgeon and the contractor.

Interval, no specimens, described as river mud	surface to 91 feet.		Recent.	
Crust, a few inches.				
Sand and coarse gravel mixed	91 feet to 113 "		Laminated Sands and Clay Marls.	Cretaceous.
Sand and coarse gravel, with some clay	113 " 125 "			
Dark sand, some greensand grains	125 " 170 "			
Sand, gray in color	170 " 180 "			
Whitish sand	180 " 200 "			
Sand, still whiter, some *lignite*	200 " 207 "			
Hard clay	207 " 211 "			
Tough clay	211 " 221 "			
Dark sandy clay, some shell	221 " 275 "			
Greenish clay, some greensand	275 " 283 "			
Sandy clay	283 " 304 "			
Whitish clay	304 " 314 "		Transition. (?)	
Red clay	314 " 318 "			
Reddish-brown clay	318 " 342 "			
Black micaceous clay	342 " 350 "			
Red clay	350 " 389 "		Plastic Clays.	
Crust, a few inches.				
Fine sand, with some *water*	389 " 400 "			
Red clay	400 " 417 "			
Hard crust, a few inches.				
Yellow clay	417 " 436 "			
White, red and lead-colored clays	436 " 470 "			
Fine white sand	470 " 474 "			
Clay, variegated colors	474 " 498 "			
Fine white sand, with *water* natural overflow, 6 gallons a minute.	498 " 505 "			
Red and yellow clays	505 " 570 "			
White sand, medium coarse grains, with *water* natural overflow, 20 gallons a minute.	570 " 574 "			

This well was prospected with the drill in the same sand last noted to the depth of 593 feet, but was finished at the depth, as above stated, of 574 feet.

A chemical analysis of the water has been made in the laboratory connected with the United States quarantine service, and we are informed that the water is "good and potable and fit for both domestic and steaming purposes."

BORED WELL AT FARNHURST, DELAWARE, FOUR MILES SOUTH OF WILMINGTON.

Depth, 211 feet.

J. H. K. Shanahan informs us that he has bored a well to the depth of 211 feet at the almshouse at Farnhurst, Delaware, four miles south of Wilmington and two and one-fourth miles north of New Castle. There were alternations of loam clay and gravel to the depth of 47 feet, below which there were encountered various beds of red and yellow clays.

DUG WELL AT LOCUST GROVE SCHOOL-HOUSE.

Elevation, 106 feet. Depth, 40 feet.

The public school-house at Locust Grove is about one-fifth of a mile north of the railroad station, and is almost if not quite exactly upon the point marked on the topographical map as the highest in the immediate vicinity, having an elevation of 106 feet. A well was dug here since last report to the depth of 40 feet, reaching, immediately below the marls, the excellent water horizon that furnishes the numerous bored wells a few miles to the westward in the vicinity of Marlton and Medford, and which were reported and illustrated by a vertical cross-section in the annual report for 1894.

The record for this well is as follows:

Surface sand		2 feet.
Reddish loamy clay	3 feet	= 5 "
Clay and sand	10 "	= 15 "
Greenish hard stiff gravel	8 "	= 23 "
Alternation of layers of ironstone and sand, containing *exogyra*, &c.	13 "	= 36 "
Water-bearing sand	4 "	= 40 "

The above verifies the record published in the report for 1894 of a well one-fifth of a mile south of the station, on the property of Ellwood Evans, where also *exogyra* was found at the depth of 30 feet, the elevation being 90 feet.

BORED WELL TWO MILES WEST OF MILFORD.

Elevation, 147 feet; diameter, 5 inches; depth, 137 feet.
Water rises within 55 feet of the surface.

W. C. Barr reports having, early in the year, bored a well on the farm of S. C. Gardiner, on the road from Ashland to Marlton, at a point about 2½ miles in a direct line southwest of the latter and nearly midway between the two. He furnishes the following record:

Commenced in bottom of a dug well, at the depth of				40	feet.
35 feet	fine yellow quicksand	40	to	75	"
6 "	gravel and coarse sand mixed	75	"	81	"
20 "	green marl	81	"	101	"
30 "	chocolate marl	101	"	131	"
6 "	sand, with *water*	131	"	137	"

The water horizon is the Marlton-Medford horizon, which occurs next below the marl series. Another horizon exists about 200 feet lower, as is demonstrated by the record of a well across the road at Mrs. John Wilkins', and which was noted in the report for 1894, the depth being 316 feet and the elevation 130 feet.

BORED WELL NEAR BUDDTOWN.

Elevation, 50 feet; diameter, 3 inches; depth, 143 feet.
Water rises within 7 feet of the surface.

Henry I. Budd has had a well bored on his farm, near Buddtown, and about two miles south of Birmingham. He has furnished the following memoranda of the strata, and has also forwarded specimens of the borings:

7 feet loam and clay				7 feet.
62 " marl, sticky	7 feet	to	69	"
2 " hard iron-stone	69	"	71	"
1 foot marl	71	"	72	"
1 " hard crust	72	"	73	"
2 feet marl	73	"	75	"
1 foot hard crust	75	"	76	"
3 feet marl	76	"	79	"
1 foot hard crust	79	"	80	"
2 feet marl	80	"	82	"
1 foot hard crust	82	"	83	"
2 feet marl	83	"	85	"
1 foot hard crust	85	"	86	"
3 feet marl	86	"	89	"
10 " shell marl	89	"	99	"
6 " shell bed, *Gryphea* and *Terebratula*	99	"	105	"
10 " black sand and marl	105	"	115	"
23 " greensand marl	115	"	138	"
2 " crust contained *Belemnites*	138	"	140	"
Coarse white sand, with *water*	140	"	143	"

The water rises within seven feet of the surface.

The water-supply is from the Marlton–Medford horizon, as is evidenced by the Belemnites in the crust near the bottom.

BORED WELL NEAR YARDVILLE.

Elevation, 70 feet; depth, 159 feet.

During the spring a well was bored on the Magnolia Stock Farm, near Yardville, to the depth of 159 feet, finding a supply of water near the top of the Plastic clays. The work was done by Stotthoff Bros., who saved a series of specimens of the borings, which was furnished the survey through Mr. C. DeHart.

From an examination of the specimens, and from information received, we make the record which follows:

	Bottom of dug well			20	feet.	
15 feet.	Blue marl	20 feet	to	35	"	Base of the Clay Marls.
7 "	"Shore" sand	35	"	42	"	
18 "	Chocolate marl, sand and gravel	42	"	60	"	
10 "	Fine black sand and *lignite*	60	"	70	"	
28 "	Shore sand	70	"	98	"	Intermediate Sands.
	Shore-sand at			130	"	
	Clay marl at			140	"	
16 "	Fine white kaolin clay, some white mica	143	"	159	"	Plastic Clays.
	Sand with *water*.					

TABLE

Annual Re

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Cretaceous 211 feet.	C	
	94 feet	

ARTESIAN TEST WELL AT BORDENTOWN.

Elevation, about 5 feet.
Diameter, six inches to first water horizon at 52 to 64 feet.
Diameter, four inches to second water horizon at 180 to 192 feet.
Boring prospected to 315 feet.
In rock, more or less micaceous, below 221 feet.
Normal level of water in both horizons, 1 foot 10 inches below the surface.

A test boring has been made to the depth of 315 feet, at Bordentown, by the American Pipe Company. The work was done under the personal supervision of John A. Durst, who carefully saved a full series of specimens of the borings, which he handed to the company together with a carefully prepared columnar chart, drawn to scale and constituting an accurate stratagraphic record. J. W. Ledoux, civil engineer for the company, courteously divided the specimens with the Survey and also permitted us to copy the record and chart, a reproduction of which we introduce herein. For the geological notes upon the extreme left the writer alone is responsible. We copy verbatim in both the other columns, J. A. Durst's record.

Two horizons, with an abundance of water, were found within the Raritan formation. The first occupies the interval between the depths of 36 and 119 feet. A six-inch casing with a twelve-foot strainer at the base was sunk into this to the depth of 64 feet from the surface. Tests were made by pumping, the yield being from 75 to 100 gallons per minute. The second horizon occurs at the depths of 163 to 195 feet. A four-inch casing, likewise with a twelve-foot strainer at the base, was sunk into this to the depth of 192 feet. On pumping, a considerable supply of water was found.

Between the two water horizons there occurs a bed, 44 feet in thickness, of fine, tough, tenacious pottery or plastic clays, which are successively red, yellow and blue in color and at times variously mottled in all these shades.

TEST BORINGS AT WHITE HORSE.

Elevation, about 6 feet; depth, 84, 107 and 110 feet.

The American Pipe Company have made three test borings near White Horse, at two localities, two and one-half and three miles

respectively, north of the well just reported at Bordentown. Through the courtesy of J. W. Ledoux, C. E., we have been furnished with specimens of the strata and with a copy of a record made by J. A. Durst, who personally supervised the drilling. The strata of the three wells are, as should be expected, much alike. For this reason we introduce the record of but one boring. This boring was on the north bank of Crosswicks creek and near the bridge on the Bordentown and Crosswicks turnpike. The record kept by J. A. Durst and tabulated by J. W. Ledoux, is as follows. We have introduced the word "lignite" several times where an examination of the specimens showed fossil wood to occur.

	Thickness of strata.	Total depths.	
Coarse sand and gravel	8 feet	= 8 feet.	Plastic clays and Gravels, = Raritan formation.
Bluish clay	8 "	= 16 "	
Bluish clay grading to white	3 "	= 19 "	
White, potters' clay	4 "	= 23 "	
White and red clay [with lignite]	8½ "	= 31½ "	
White clay	1½ "	= 33 "	
Darker bluish clay	3 "	= 36 "	
Blue clay, much rotten wood [lignite]	4½ "	= 40½ "	
Thin alternation of fine sand and blue clay, each a few inches thick only, [some lignite]	27½ "	= 68 "	
Coarse sand and thin clay beds, sand beds thickest	9 "	= 77 "	
Coarse sand and fine gravel. Water-bearing 77 to 84 feet.	25 "	= 102 "	
Whitish clay	5 "	= 107 "	

The clays, between the depths of 19 and 40 feet certainly, and possibly between the depths of 8 and 40 feet, are the equivalent of the 44 feet of clays constituting at Bordentown the septum between the two water horizons there. The water in the gravels below 77 feet is the equivalent of the second or lower horizon at Bordentown. This well is about two and two-fifths miles back on the dip of the strata from the well at Bordentown.

Sec. 1b.—Wells in the Northern Part of the Cretaceous Belt.

ARTESIAN WELLS AT NORTHWEST ASBURY PARK.

No. 1.—Elevation,	10 feet (?);	diameter,	$4\frac{1}{2}$ inches;	depth, 500 feet.
No 2.— "	10 feet (?);	"	6 "	" 520 "
No. 3.— "	25 feet (?);	"	6 "	" 560 "

Wells Nos. 1 and 2 overflowed at the surface 40 gallons per minute each.
In Well No. 3 the water rose nearly to the surface.

Uriah White informs us that he has drilled three wells for the West Asbury Water Company. They are situated slightly more than a mile from the Atlantic Ocean, at the head of one of the arms of Deal Lake and on the south side thereof, near where Asbury avenue crosses the same. The wells have respectively the depths noted above. Nos. 1 and 2, being on low ground on the margin of the lake and of the stream running into it, overflow, but in Well No. 3, which is on higher ground, the water does not overffow but rises nearly to the surface. All three wells draw from the same water stratum, which is the equivalent of the horizon at Asbury Park, the top of which is reached at the depth of 525 feet.

After some correspondence with Uriah White, we have estimated the elevation of each well to be, approximately, as above.

BORED WELL NEAR HOLMDEL, NEW JERSEY.

Elevation, 90 feet; diameter, 4 inches; depth, 575 feet.
Water rises within 20 feet of the surface.

A few years since a well was drilled at the Gideon and Daly stock farm, near Holmdel, of which Charles D. Pierce, of the firm who did the work, writes as follows:

"The depth of this well was about 575 feet. The formation was first sandy soil and then alternate strata of clay and quicksand the entire depth. We passed through, I believe, what you would call marl. A small quantity of water was found at different points below 50 feet down to 540 feet. The water above 540 feet was found to contain more or less quicksand and it was found impossible to separate it from the water. From 540 to 575 feet we found coarse sand and gravel. The well is what you might call inexhaustible, as it could not be exhausted by any pump that could be placed in a 4-inch well. After we reached

a depth of 540 feet the water stood within 20 feet of the surface, but never raised to the surface nor flowed."

On placing this well in its proper position upon a vertical cross-section, now in preparation, of the northern portion of southern New Jersey, it seems most probable that the troublesome quicksands above noticed belong to the clay marls, and that the water-bearing gravels beneath, which were utilized for supply, belong near the base of the same, that is, near the base of the Matawan.

ARTESIAN WELLS AT LAKEWOOD, N. J.

Elevation, 50 feet; depths, 475 feet and 612 feet.

In the annual reports for 1884 and 1885, there occur notices of a well at the Laurel House, Lakewood, put down to the depth of 475 feet. About the year 1890, Uriah White bored another well at Lakewood, to a lower water-horizon, the well reaching a depth of 612 feet.

We are enabled, from an examination of a series of specimens from the first well, preserved at the Laurel House, and from some further information contained in a letter from Uriah White respecting the second well, to present a much more detailed record of strata than has appeared in former reports. The record is as follows:

Depth of specimens in feet.			
43	Yellowish sand		Beacon Hill. (?)
50	Brownish sandy clay		Miocene.
75	Brownish sandy clay		
112	Brownish sand, medium coarse		
135	Brownish, coarse, sandy clay		
168	Sand, considerable greensand grains. Upper layer, Upper marl		Eocene and Cretaceous.
170	Light-colored clay	Ash marl. =Middle layer, Upper Marl bed.	
200	Light-colored clay		
240	Light-colored sandstone, some greensand, slightly calcareous		
245	Light-colored clay, with some sand		
270	Sandy clay, darker		
280	Greensand		
350	Greensand	Lower layer, Upper Marl bed.	

Depth of specimens in feet.			
355	Clay, darker than at 170, &c.		Cretaceous.
360	Greensand		
370	Greensand, with shell (*Terebratula*, &c.)	Middle Marl bed.	
390	Greensand		
450	Yellowish-gray sand		
460	Yellowish-gray sand		
	All the above specimens were from well No. 1. The continuation of the record for well No. 2, as furnished by the contractor, is as follows:		
Specimens not furnished.			
460 to 468	Sand and shells	Lower Marl bed.	
468 to 560	Dark clay or mârl	Clay marls.	
560 to 612	Light gray sand, with thin layers of clay		

ARTESIAN WELLS AT BELMAR.

Three wells	Depth, 80 to 85 feet.	Miocene.
Three wells	Depth, 480 and 495 feet.	Cretaceous.
Two wells	Depth of each, about 660 feet.	

Kisner & Bennett inform us that during the year they have drilled three wells at Belmar to the depth of from 80 to 85 feet, for which they furnish the following record of strata.

The wells are supplied from sands at the base of the Miocene.

	Thickness.	Total depths.
Soil, &c.	9 feet	= 9 feet.
Tough blue clay	6 "	= 15 "
Coarse sand	20 "	= 35 "
Greenish quicksand	5 "	= 40 "
Sand and gravel, with shell	2 "	= 42 "
Rotten stone (Miocene clay)	36 "	= 78 "
Coarse blue sand and gravel, grains sharp and angular, with *water*	4 "	= 82 "
Rotten stone (Miocene clay), prospected	9 "	= 91 "

The same contractors also inform us that they have recently drilled two deeper wells, one with a depth of 480 feet and the other with a depth of 495 feet, both of which draw from the sands below the true marl series—this horizon being identical

with that reached at Asbury Park at about the depth of 400 feet, and the same as the Marlton-Medford horizon.

In the annual reports for 1884 and 1885 there is noticed a well at the residence of Eben C. Jayne with a depth of 480 feet. Through the intervention and courtesy of C. Henry Kain, a series of specimens of the borings that had been preserved has been recently received. As this well was put down by the old process, which furnishes the earth and clays in an unchanged condition, and thus enables us to judge better as to the character of the strata, we furnish below a description of each specimen:

Depth of specimens, in feet.			
200	Light colored clay	Ash marl.	Upper Marl bed.
260	Light colored clay		
270	Light colored clay		
340	Greensand marl, dark color		
360–380	Greensand marl, lighter, with shell fragments, probably Terebratula		Middle and Lower Marl Beds.
400	Coarse sand, some greensand, fragments of shell,		
415	Greensand		
440	Greensand		
450	Greensand		
460	Greensand		
465	Light colored marl, very calcareous with acid treatment		
470	Greensand		
475	Sand, white quartz and greensand grains mixed,		
480	Greensand, with fragments of shell		
480	Gray sand and water		

With the above specimens was one package of shells marked 360 to 460 feet, among which we recognize *Gryphæostrea vomer* and *Belemnitella mucronata*, and a number of fragments of a ponderous shell, probably *Gryphea vesicularis;* also a pecten.

Kisner & Bennett further report that there are two other wells at Belmar, which have each a depth of about 660 feet, that draw from the laminated sand horizon which is met with at Asbury Park at the depth of 525 feet. This horizon is in the laminated sands at the top of the clay marls.

We therefore have demonstrated at Belmar the depth to one Miocene and to two Cretaceous horizons. The Miocene horizon, while furnishing a considerable amount of water, does not furnish

at this point near so large and abundant supply as the two Cretaceous horizons, and particularly the lower of the two.

We are not as yet able to correlate the Miocene horizon with either of the horizons in beds of that age that furnish so many wells south of Barnegat. For further information about these Miocene wells, see page 163, under the head of Wells in the Miocene.

ARTESIAN WELL AT BAY HEAD.

Elevation, 10 feet; depth, 885 feet.
First water horizon, 710 feet.
Second water horizon, 885 feet.

From an interview with Kisner & Bennett, we learn that a well has been put down by them at Mantoloking to the depth of 885 feet. This well draws from the laminated sands which are at the top of the Clay marls proper and below the marl series. The bottom of the Miocene clay, commonly called "rotten stone," was passed in this boring at the depth of 220 feet.

A well at this locality, noted in the report for 1887, found water at the depth of 710 feet. It is, therefore, demonstrated thera exist at this locality two water horizons, viz., at the depth of about 710 and 885 feet, respectively. These two horizons are evidently quite constant, since they have been found at Asbury Park, Ocean Grove, Belmar and Sea Girt, all of which are farther back on the dip of the beds, and at Mantoloking, which is farther out on the dip. The depths to those horizons at each of the localities named is as follows:

	Upper horizon.	Lower horizon.
Asbury Park	400 feet.	525 feet.
Ocean Grove	400 "	525 "
Belmar	500 "	650 "
Sea Girt	600 "	735 "
Bay Head	710 "	885 "
Mantoloking	790 "	922 "

We are not aware that these horizons have been tapped along the coast south of Mantoloking, the wells in that direction drawing from horizons above them. Considering, however, the quantity and quality of the water, especially from the lower of the two, it may yet become desirable to sink wells to them, since, in all probability, they continue many miles southward, and possibly entirely underlie the rest of Southern New Jersey.

ARTESIAN WELL ONE MILE NORTH OF BAY HEAD.

Elevation, 10 feet; depth, 813 feet.

Kisner & Bennett inform us of a well not heretofore noted in these reports, that was put down by them a few years since at the Beacon-by-the-Sea, about one mile north of Bay Head.

This well was tubed with a 4½-inch casing to the depth of 200 feet, or about to the bottom of the Miocene clays, known to the well-drillers as "rotten stone," and to the top of the marl series. Below this a 3-inch casing was continued to the depth of 813 feet, when a flow of water of excellent quality was obtained at the surface, amounting to 85 gallons a minute. On a test being made by adding casing to the top of the well, the water rose therein to 86 feet above the surface.

This well obtains its supply from the laminated sands or upper division of the Clay marls—the horizon being the same as that supplying the well at Bay Head, at the depth of 885 feet, as per the record immediately preceding, and which is the equivalent of the 525-foot horizon at Asbury Park.

ARTESIAN WELLS AT MANTOLOKING.

Revision of Record from Annual Report for 1895.

Well No. 1; depth, 132 feet. Water rises nearly to the surface............................	=	Probably the 800-foot horizon at Atlantic City, in the *Miocene*.
Well No. 2; depth, 790 feet. Water rises 33 feet above the surface. Flow at the surface, 25 gallons a minute................	=	400-foot horizon at Asbury Park, in the *Cretaceous*.
Well No. 3; depth, 922 feet. Water rises 42 feet above the surface. Flow at the surface, 60 gallons a minute................	=	525 to 575-foot horizon at Asbury Park, in the *Cretaceous*.

Kisner & Bennett having kindly favored us with the additional data above tabulated respecting the different heights to which the water from the various horizons would rise, and also the amount of natural flow per minute at the surface, the record of these wells is again introduced from the report for 1894:

"At various times, since about the year 1887, there have been made three borings at Mantoloking by Kisner & Bennett.

"The first well was noticed in the annual report for 1889,

wherein it is stated to have a depth of 175 feet.* A second well was afterwards bored to 790 feet—to the 400-foot water-bearing sand of Asbury Park, which was here found occupying the interval between the depths of 690 and 740 feet.

"Still later another well was sunk to the depth of 922 feet, drawing water from a sand between 872 and 922 feet. This horizon is probably the equivalent of 525 to 575 feet at Asbury Park."

BORING AT TOMS RIVER.

Elevation, 40 feet; depth, 745 feet.

There is a boring at Toms River that was prospected some years since to the depth of 745 feet. About 100 feet more in depth would have probably found the 400-foot horizon of Asbury Park.

The geological facts learned are as follows:

Coarse yellow gravel.........at 28 feet.			
Yellow sand, fine.............at 70 "			
Coarse yellow sand...........at 80 "			
Brownish-gray, quartzose sands, varying from medium fine to medium coarse..........................	90 " to 165 feet.	Miocene.	
Some lignite at 165 feet.			
Gray sand, gritty, with two clay seams, to...............	365 "		
Greensand marl...............	480 "	Upper Greensand layer of Upper Marl bed=Blue Marl.	
Light-green earthy material, highly calcareous, to..............................	600 "	Middle layer of Upper Marl bed = Ash Marl.	Eocene.
Light-colored clay, slightly greenish cast, no greensand nor any micro-organism, at....................	635 "	The base of this division is probably the Upper Greensand layer of Upper Marl bed = Green Marl.	
Sandy material, containing a great deal of greensand, to................................	745 "		Cretaceous.

* Kisner & Bennett have recently informed the writer that the water furnished to well No. 1 came from a coarse sand at the depth of 126 to 182 feet.

ARTESIAN BORING AT BARNEGAT PARK.

Elevation, 50 feet; depth, 670 feet.

At Barnegat Park there is an unfinished boring with a depth of 670 feet. The surface deposit consists of a few feet of gravel with fossiliferous pebbles. The top of the Miocene clay, commonly called rotten stone by the well-drillers, was found at the depth of 230 feet.

From specimens obtained and from information received we collate the subjoined record.

Gravel, with fossiliferous pebbles, surface to	10 feet.
Then fine gray sand	
Yellowish fine sand, shade of brown sugar, at	50 "
Yellow clay seam at	46 "
Yellow clay and sand at	100 "
Then fine, clean white sand	
Medium coarse orange-colored sand at	150 "
Fine gray sand at	175 "
Brownish clay at	239 "
"Rotten stone" at	280 "
Marl, consisting of light and dark greensand grains, at	330 "
Sponge spicules seen under microscope.	
Coarse gray sand, almost gravel, some glauconite mixed, at	398 "
Marl and sand at	500 "
Marl and sand at	524 "
Clayey marl and sand at	534 "
Stopped in greensand marl at	670 "

We regard the bottom of this well as near the base of the Upper Marl bed. A depth 230 to 270 feet greater would probably have found a desirable water horizon, viz., the 400-foot horizon of Asbury Park, while a depth 125 to 150 feet still greater would probably reach the 525-foot horizon at Asbury Park.

Artesian Wells in Cretaceous Strata on Long Island, New York.

Correlation with the Cretaceous in New Jersey.

ARTESIAN WELL, BARREN ISLAND, JAMAICA BAY, SOUTH COAST OF LONG ISLAND.

Elevation, high-tide level; diameter, 6 inches; depth, 720 feet; overflows 50 gallons a minute.

Thomas B. Harper has successfully finished a well on Barren Island, on the south coast of Long Island, N. Y., at the entrance of Jamaica Bay, the location being east of Coney Island and west of Rockaway Beach. The well is about on the line of strike with the New Jersey Cretaceous beds at Point Comfort and Keyport. The depth is 720 feet, the well draws from a coarse, yellowish-white gravel, between the depths of 712 and 720 feet.

By a test made at the time of finishing the well, it was found to have a natural overflow from the top of the casing, some five feet above the surface, of fully 50 gallons per minute. The water has since been piped so as to flow over the top of and into a tank on somewhat higher ground near by. The top of the tank is about fifteen feet higher than the surface where the well is located. The quality of the water is said to be excellent.

Records and specimens of these borings were not kept. We have, however, been furnished, from memory, with the following general notes of the succession of strata:

Whitish sand for some distance down from the surface......				
Heavy gravels and cobbles at..........			140	feet.
"Reddish" (?) sand..........				
Dark-colored conglomerate, quartz-grains and pebbles size of mustard to that of shellbarks and walnuts at............			218	"
Cobbles at and some distance below..........			230	"
Whitish sand..........				
"Cemented material"—feldspar and quartz..........	495	feet to	500	"
Bluish, soft marl (?)..........	500	"	560	"
Alternations of sands and clays, each 15 to 20 feet thick......	560	"	660	"
Red (?) clay at..........			706	"
Yellowish-white, coarse sand and fine gravel; water-bearing..	712	"	720	"
Whitish clay, prospected 4 feet or from..........	720	"	724	"

This boring in its lower portion, say below the depth 230 feet or perhaps slightly lower, demonstrates the probable existence and extension beneath Long Island of the Clay-marl or Matawan formation of New Jersey, while near the base, say below 700 feet, there are possibly indications in the color of the gravels of a change from these Matawan beds to the Plastic clays and gravels of the Raritan formation of New Jersey.

The water horizon opened by this well can probably be relied upon to supply fresh water to many of the beaches to the eastward along the southern coast of Long Island.

SECOND ARTESIAN WELL ON BARREN ISLAND, L. I., N. Y.

Since the above was written, and before the same was printed, and therefore of later date than this report bears, a second well closely adjacent to the first one has been put down on Barren Island to the same water horizon, which was prospected to the depth of 740 feet. From this well we have received specimens of the borings from 70 feet downward, taken every 10 feet. These were kindly furnished by the contractor, Thomas B. Harper. With the specimens before us, we make the following condensed record, which is more accurate than the one given above :

Interval, no specimens, ...	Surface to 70 feet.			
Brownish sands, sometimes slightly yellowish and sometimes slightly reddish in cast, ...	70 feet to 130 "	Glacial, &c. (?)		Pleistocene.
Reddish-brown and yellowish-brown sands, same as next above, with the addition of large pebbles and cobbles, &c., ...	130 " 220 "			
Whitish sands, ...	220 " 240 "	Transitional.	Matawan.	Cretaceous.
Brown sands, ...	240 " 260 "			
Bluish-white sands, some lignite throughout,*	260 " 500 "	Laminated Sands (?)		
Dark, micaceous, sandy clay, no lignite, .	500 " 690 "	= Clay Marls (?)		
Yellowish-white sand, coarse, at 700 to 720, water-bearing, ...	690 " 740 "	Upper part of Plastic clays and gravels.	Raritan.	

On comparing the specimens from this boring with a very full series of specimens from the deepest boring (1,321 feet) at Asbury Park, a record of which occurs in the Annual Report for 1895, page 73, there is seen to be an exact correspondence in the beds in this well below 260 feet with those at Asbury Park below 950

* A stratum of sandy clay with a reddish cast occurs interbedded at 390 to 400 feet.

feet. A change of identically the same nature also occurs at the two places, at the depth of 500 feet at Barren Island and that of 1,175 feet at Asbury Park. The succession of the beds from above downwards and their correspondence at the two localities is as follows:

Descriptions.	Asbury Park, N. J. Depths in feet.	Barren Island, L. I. Depths in feet.
Very dark heavy clays and sands with *glauconitic* or greensand grains throughout	600 to 950	Wanting.
Light-colored sandy clays and sands, *lignite* throughout; no greensand	950 to 1175	260 to 500
Slightly darker clays and sands, notably *micaceous;* no greensand and no lignite ...	1175 to 1321	500 to 690
Exogyra and *other shells* at Asbury Park at the depth of 1,195 feet.		
White gravel and coarse sand, *water-bearing;* overflows at Barren Island 50 gallons a minute from each of the two six-inch wells there..	....	690 to 740

This water horizon was not reached at Asbury Park, the boring not having been continued far enough. It probably occurs there at the depth say, of 1,360 to 1,425 feet. The whitish color of the sands and gravels of the Barren Island wells in which this horizon occurs may be described as very slightly yellowish-white in contrast with the color of all the sands that occur above, say between the depths of 260 and 690 feet. These latter are either dead-white or very slightly bluish-white in cast. The same change in shade is characteristic of the continuation of the beds southwestward into New Jersey, as has been observed by the writer in borings furnished him from various wells in the neighborhood of Camden. In the latter region this change in the color of the gravel and sands marks the change from the Clay marls to the Plastic Clay series, or in other words from the Matawan to the Raritan formation. Both of these are Cretaceous and occur in the order just named below the beds of the Marl or true greensand series, which latter are entirely wanting in the Barren Island section.

In this connection the succeeding reports of wells at Woodhaven and at other places in the region north of Jamaica bay should be read.

Deep Bored Wells in the Vicinity of Jamaica Bay, Long Island, N. Y.

		Location.	Elevation, in feet.	Diameter, in inches.	Pleistocene. Glacial in part or in whole. Sands and Gravels.	Probably Matawan Division of the Cretaceous =Clay Marl. Blue Clays and Whitish Sands.	
Brooklyn Water Department.	T. W.* No. 5	Foot of Ridgewood Reservoir Hill	61.8	5	Surface to 193 ft.	193 ft. to 284 ft.	Water-bearing.
	T. W. No. 6	Hollis	58.6	5	Surface to 302 ft.	302 ft. to 406 ft.	
	....	Woodhaven, one well	35.6	......	Surface to 213 ft.	213 ft. to 577 ft.	Stopped on rock said to [be Gneiss (?).
	T. W. No. 4	Spring Creek Pumping Station	8.6	5	Surface to 126 ft.	126 ft. to 148 ft.	Water-bearing.
	T. W. No. 11	Jamaica, South	19.2	5	Surface to 95 ft.	95 ft. to 198 ft.	Water-bearing.
	T. W. No. 17	West of Aqueduct R. R. Station	10.6	5	Surface to 95 ft.	95 ft. to 191 ft.	
	T. W. No. 16	East of Aqueduct Station	12.7	5	Surface to 135 ft.	135 ft. to 154 ft.	
	T. W. No. 10	Northeast of Springfield	9.8	5	Surface to 89 ft.	89 ft. to 357 ft.	
	T. W. No. 18	Lincoln Avenue, East of No. 16	10.3	5	Surface to 115 ft.	115 ft. to 198 ft.	
	S. W.† No. 5a	Jameco	....	10	Surface to 84 ft.	84 ft. to 160 ft.‡	Flowing.
	S. W. No. 2a	Jameco	2.2	8	....	Depth, 154 ft.	Flowing.
	T. W. No. 8x	Jameco	2.0 (?)	2	....	Depth, 140 ft.	Water-bearing.
	S. W. No. 3a	Jameco	2.1	8	....	Depth, 150 ft.	Flowing.
	S. W. No. 4a	Jameco	1.7	8	Surface to 70 ft.	79 ft. to 150 ft.	Flowing.
	T. W. No. 9x	Jameco	2.0	2	....	Depth, 140 ft.	Water-bearing.
	S. W. No. 1a	Jameco	1.1	1	....	Depth, 150 ft.	Flowing.
	T. W.	Baisley's	6.7	5	Surface to 104 ft.	104 ft. to 198 ft.	Water-bearing.
	T. W. No. 1	One-half mile east of Jameco	5.5	5	Surface to 88 ft.	88 ft. to 155 ft.	Water-bearing.
	T. W. No. 2	One-quarter mile east of No. 1	7.4	5	Surface to 84 ft.	84 ft. to 257 ft.	Water-bearing.
	T. W. No. 3	One-half mile east of No. 2	9.8	5	Surface to 87 ft.	87 ft. to 277 ft.	

* T. W.—Test Wells. † S. W.—Service Wells. ‡ In Jameco well, 5a, heavy gravel with bowlders were found at the bottom. Similar bowlders and gravels were found in the Barren Island wells at the depths of 140 feet to 200 feet.

Divisions at Woodhaven.	Description.	Woodhaven.	Barren Island.		
1.	Sands and gravels. "Yellowish-brown or rusty." E. Lewis, Jr.	Surface to 213 ft.	Surface to 220 ft.	Glacial.	Pleistocene.
	Light, colored, sandy clays and sands with considerable lignite.	Wanting.	220 ft. to 450 ft.	Matawan.	Cretaceous.
2.	Dark gray clay.......... 39 ft. Lighter colored clay.. 46 " Dark gray clay, a little lignite.. 60 " 145	=213 ft. to 358 ft.			
3.	Gray sand... 17 ft. Gray sandy clay.......... 10 " Gray sand, a little lignite......... 32 " 59	=358 " 417 "	450 ft. to 690 ft. =1175 ft. to 1321 ft.+ at Asbury Park, N. J.		
4.	Clay............ 19 ft. Sand........... 7 " Sandy clay... 13 " 39 "	=417 " 456 "			
5.	White coarse sand, almost gr'v'l 14 ft. Clay............ 5 " White gr'v'l. 35 " Fine white sand......... 5 " 59	=456 " 515 "	690 ft. to 740 ft.+ Water bearing.	Raritan.	
6.	Dark clay.... 3 ft. White kaolin clay..... 22 " Dark clay.... 16 " 41 "	=515 " 556 "	Not reached.		
7.	Rock........... 11 ft.	=556 " 577 "			

From the data in hand we provisionally estimate the dip of the Cretaceous beds near the base of these wells at about 45 feet per mile S. S. E.

The well at Woodhaven is said not to have been productive of much water. In view of the fact, however, that the two wells on Barren Island each overflowed from a six-inch casing, 50 gallons of water per minute, we deem it most probable that the lack of supply at Woodhaven was due to the less perfect methods of drilling known and practiced at the time the latter well was put down, and that the gravels near the base can be reasonably expected to furnish a good supply of water along the southern side of Long Island.

ARTESIAN WELL ON BARNUM ISLAND, WEST OF HEMPSTEAD BAY.

Thirteen miles east of Barren Island.
No satisfactory supply of water. Depth 383 feet.

A well was put down probably about the year 1876 on Barnum Island, to the depth of 383 feet. Specimens of the borings are preserved in the Museum of the Long Island Historical Society. The Pleistocene gravels extend to the depth of 70 feet, below which there are alternations of clays, sandy clays and sands darker in color than those below the Pleistocene gravels at Woodhaven and Barren Island, and differing in that these contain much more lignite, while iron pyrites abounds throughout. We regard these beds as stratigraphically higher than those at the two other places just named, but belonging, however, to the same formation, viz., the Matawan. Below are the writer's notes made directly from the borings.*

Yellow gravel	surface	to 15 feet.	Pleistocene.
Dark clay	15 feet	to 22 "	
Yellow gravel, changing near the base to buff sand	22	" 70 "	
Dark clay with lignite	70	" 75 "	
Stiff dark clay	75	" 126 "	
Heavy gravel, with white and different colored pebbles	126	" 129 "	
Sand	129	" 147 "	
Sand and gravel	147	" 168 "	
Sand with lignite throughout	170	" 200 "	
Sandy clay at		225 "	Matawan.
Sand at		243 "	Cretaceous.
Gray sand, much lignite throughout	245	" 290 "	
Dark clay at		300 "	
Dark clay with lignite at		350 "	
Micaceous sand at		353 "	
Sand and clay	360	" 383 "	

*For a more detailed record by N. H. Darton consult Bulletin No. 138, U. S. Geological Survey, pp. 32, 33.

WELLS OF THE BROOKLYN WATER DEPARTMENT AND OTHER ARTESIAN AND BORED WELLS IN THE REGION NORTH OF AND SURROUNDING JAMAICA BAY AND SOUTH OF THE MORAINE HILLS.

On the lower land south of the moraine hills, upon which are situated East New York, Ridgewood, Woodhaven, Jamaica, Hollis and Queens, and between those places and Jamaica bay, there are a considerable number of bored wells of various depths, which we tabulate beyond for the purpose of correlation with the Barren Island and other well records immediately preceding. Detailed records of many of these wells, describing minutely the various strata, have recently appeared in Bulletin 138 of the United States Geological Survey, "Artesian Well Prospects in the Atlantic Coastal Plain," by N. H. Darton. We, however, indicate only the larger divisions. These we have made out, in every instance, except two,* from a personal inspection of specimens of the borings, most of which have been preserved in the office of the Department of City Works of Brooklyn, though a few are displayed in the collections of the Long Island Historical Society. The latter were carefully collected and arranged some years since by the late Elias Lewis, Jr., who was much interested in the study of the geology of Long Island, and wrote a number of papers thereupon. An inspection of the borings thus preserved has assisted us materially in the solution of the stratification.

The borings belonging to the Brooklyn water department are in the office of the department. They are arranged in tubes to scale, and are permanently kept in a rack in an upright position. To I. M. DeVarona, engineer of water-supply, we are indebted for the opportunity to examine and study them. We have assumed it as most probable that the underlying beds dip from N. N. W. to S. S. E., and have arranged the wells in the following table, in their proper position, in that order along the line of the dip:

* The exceptions are wells Nos. 20 and 21, and for these we have been furnished with copies of the records on file in the water department.

Deep Bored Wells in the Vicinity of Jamaica Bay, Long Island, N. Y.

		Location.	Elevation, in feet.	Diameter, in inches.	Pleistocene. Glacial in part or in whole. Sands and Gravels.	Probably Matawan Division of the Cretaceous =Clay Marl. Blue Clays and Whitish Sands.	
Brooklyn Water Department.	T. W.* No. 5	Foot of Ridgewood Reservoir Hill	61.8	5	Surface to 193 ft.	193 ft. to 284 ft.	Water-bearing.
	T. W. No. 6	Hollis	58.6	5	Surface to 302 ft.	302 ft. to 406 ft.	[be Gneiss (?).
	....	Woodhaven, one well	35.6	......	Surface to 213 ft.	213 ft. to 577 ft.	Stopped on rock said to
	T. W. No. 4	Spring Creek Pumping Station	8.6	5	Surface to 126 ft.	126 ft. to 148 ft.	Water-bearing.
	T. W. No. 11	Jamaica, South	19.2	5	Surface to 95 ft.	95 ft. to 198 ft.	Water-bearing.
	T. W. No. 17	West of Aqueduct R. R. Station	10.6	5	Surface to 95 ft.	95 ft. to 191 ft.	
	T. W. No. 16	East of Aqueduct Station	12.7	5	Surface to 135 ft.	135 ft. to 154 ft.	
	T. W. No. 10	Northeast of Springfield	9.8	5	Surface to 89 ft.	89 ft. to 357 ft.	
	T. W. No. 18	Lincoln Avenue, East of No. 16	10.3	5	Surface to 115 ft.	115 ft. to 198 ft.	
	S. W.† No. 5a	Jameco	....	10	Surface to 84 ft.	84 ft. to 160 ft.‡	Flowing.
	S. W. No. 2a	Jameco	2.2	8	....	Depth, 154 ft.	Flowing.
	T. W. No. 8x	Jameco	2.0 (?)	2	....	Depth, 140 ft.	Water-bearing.
	S. W. No. 3a	Jameco	2.1	8	....	Depth, 150 ft.	Flowing.
	S. W. No. 4a	Jameco	1.7	8	Surface to 70 ft.	79 ft. to 150 ft.	Flowing.
	T. W. No. 9x	Jameco	2.0	2	....	Depth, 140 ft.	Water-bearing.
	S. W. No. 1a	Jameco	1.1	1	....	Depth, 150 ft.	Flowing.
	T. W.	Baisley's	6.7	5	Surface to 104 ft.	104 ft. to 198 ft.	Water-bearing.
	T. W. No. 1	One-half mile east of Jameco	5.5	5	Surface to 88 ft.	88 ft. to 155 ft.	Water-bearing.
	T. W. No. 2	One-quarter mile east of No. 1	7.4	5	Surface to 84 ft.	84 ft. to 257 ft.	Water-bearing.
	T. W. No. 3	One-half mile east of No. 2	9.8	5	Surface to 87 ft.	87 ft. to 277 ft.	

* T. W.—Test Wells. † S. W.—Service Wells. ‡ In Jameco well, 5a, heavy gravel with bowlders were found at the bottom. Similar bowlders and gravels were found in the Barren Island wells at the depths of 140 feet to 200 feet.

Deep Bored Wells in the Vicinity of Jamaica Bay, Long Island, N. Y.—Continued.

		LOCATION.	Elevation, in feet.	Diameter, in inches.	PLEISTOCENE. GLACIAL IN PART OR IN WHOLE. Sands and Gravels.	PROBABLY MATAWAN DIVISION OF THE CRETACEOUS =CLAY MARL. Blue Clays and Whitish Sands.	
Brooklyn Water Depar't.	T. W. No. 8	West of Springfield	10.0	5	Surface to 72 ft.	72 ft. to 295 ft.	Water-bearing.
	T. W. No. 7	One-quarter mile east of No. 8	16.0	5	Surface to 65 ft.	65 ft. to 419 ft.	Slightly water-bearing.
	T. W. No. 9	South of Springfield P. O.	10.3	5	Surface to 110 ft	110 ft. to 271 ft.	
	T. W. No. 12	One-half mile east of No. 9	18.0	5	Surface to 130 ft.	130 ft. to 406 ft.	
	T. W.* No. 13	Rosedale R. R. Station	21.5	5	Surface to 105 ft.	105 ft. to 410 ft.	
	T. W. No. 14	One-half mile east of No. 13	16.7	5	Surface to 101 ft.	105 ft. to 390 ft.	
	T. W. No. 15	Clear Stream Pumping Station	13.6	5	Surface to 64 ft.	64 ft. to 190 ft.	
	T. W. No. 19	Watts Pond Pumping Station	9.4	5	Surface to 71 ft.	71 ft. to 208 ft.	
	T. W. No. 20	Valley Stream	14.6	5	Surface to 78 ft.	78 ft. to 242 ft.	
	T. W. No. 21	East of Valley Stream	15.0 (?)	5	Surface to 65 ft.	65 ft. to 410 ft.	
Queens Co. Water Works.	Well No. 1	Near Fenhurst	5.0 (?)	......	......	Depth, 152 ft.	Flows largely. ‡
	Well No. 2	Near Fenhurst	5.0 (?)	......	......	Depth, 158 ft.	Flows largely. ‡
	Well No. 3	Near Fenhurst	5.0 (?)	......	......	Depth, 183 ft.	Flows largely. ‡
	Well No. 4	Near Fenhurst	5.0 (?)	......	......	Depth, 148 ft.	Flows largely. ‡
......		Barren Island, Well No. 1	5.0 (?)	......	Surface to 220 ft.	220 ft. to 720 ft. †	Flow 50 gallons a minute each.§
......		Barren Island, Well No. 2	5.0 (?)	......	Surface to 220 ft.	220 ft. to 740 ft. †	
......		Barnum's Island, one well	5.0 (?)	......	Surface to 72 ft.	72 ft. to 383 ft.	

* T. W.—Test Wells. † In the wells on Barren Island, the clays from 510 to 690 feet are darker and more micaceous than those from 220 to 510 feet. The water-bearing sands from 690 to 720 and 740 feet, in comparison with the *white* sands interbedded from 220 to 510 feet, may be described as slightly *yellowish*-white in color. The depth of 690 feet may, perhaps, mark the transition from the Matawan (?) to the Raritan formation. ‡ Copied from N. H. Darton, Bulletin No. 138, U. S. Geological Survey.
§ The water is found below the depth of 690 feet in coarse white sand and fine gravel.

All of the wells noted in the table first pass through a greater or less thickness of superficial sands and gravels—the gravel being at times very heavy and containing what may be called cobble-stones. They then enter beds of an entirely different nature, consisting of bluish sandy clays and whitish sands.

The deepest wells, the two on Barren Island, in the lowest 220 or 240 feet of their depths, penetrated a somewhat darker and more decidedly micaceous clay. Excepting the well at Woodhaven, none of the other wells entered this stratum, though wells No. 7 and No. 21 probably reached quite close thereto. It should, perhaps, also be noted that the Barren Island wells, before entering the above-noted superficial sands and gravels, penetrated a more recent bed of mud to the depth of about 70 feet.

Wells Nos. 5 and 6 are upon higher ground than the others, being situated part way up the slopes of the moraine hills, and are some fifty feet higher than the average elevation of the other wells. In well No. 5 the superficial upper sands to the depth of 193 feet closely resemble the sands and gravels of the Barren Island wells from the depth of 70 feet to that of 220 feet. In well No. 6 occurs the greatest thickness—302 feet—of these same superficial sands and gravels that has been met with in these borings.

These superficial sands and gravels we regard as Pleistocene in age. They are probably in part, if not wholly, of glacial origin. The clays and sands below them we correlate with the Matawan division of the Cretaceous of New Jersey. Of the wells noted on Long Island, only those on Barren Island and at Woodhaven penetrate entirely through the beds of this division, if indeed they do; but the color of the water-bearing gravels at their base inclines us to the view that they form the transition bed to the Raritan or Plastic Clay division of the Cretaceous. Outcrops of plastic clays occur at various points along the northern shore of the island.

If we may judge from the darker color of the clays and the greater prevalence of lignite shown in the borings preserved in the museum of the Long Island Historical Society from the well 383 feet deep at Barnum's Island, that well, below the depth of 70 feet, likewise entered the Matawan formation, penetrating, however, most of the way down a portion thereof stratigraphically higher than occurs beneath Barren Island; the latter, prob-

ably, being westward of the point where the upper part of the Matawan bed approaches the surface beds.

A careful inspection of the borings from the Woodhaven well and comparison of the same with the borings from the Barren Island wells reveals a decided lithological resemblance in the materials, especially in the yellowish white cast of the gravel at the bottom of each. As already noted we find the depth of 556 feet at Woodhaven corresponds with the depth of 690 feet at Barren Island.

Sec. 2.—Wells in the Miocene Belt.

ARTESIAN WELLS AT BELMAR.

Depth, 80 feet.

There are at Belmar several wells put down to an average depth of about 80 feet to the sands at the base of the Miocene deposits. These sands are immediately below the clay bed that is locally known to the well-drillers by the name of "rotten stone." The writer has not had the opportunity to examine any of this clay from the Belmar wells, but specimens from what is no doubt the equivalent stratum at Asbury Park, three miles to the northward, has been found to contain marine diatoms, among them Heliopelta, which the writer has demonstrated in this report is characteristic of the base of the Miocene. See pages 172 and 173. Three of these Miocene wells at Belmar, with depth of 80 to 85 feet, are noted in connection with deeper wells to two of the Cretaceous horizons. See pages 148 and 151.

MIOCENE ARTESIAN HORIZON AT MANTOLOKING.

Depth, 132 feet.

An artesian water horizon occurs at Mantoloking, at the depth of 126 to 182 feet, in sands, probably the equivalent of the 800-

foot Atlantic City horizon. See report, page 152, of Cretaceous wells at this locality.

SECOND ARTESIAN WELL AT HARVEY CEDARS ON LONG BEACH.

**Elevation, 3 feet; diameter, 4½ inches; depth, 500 feet.
Water rises 6 feet above tide; flow, 120 gallons a minute.**

Early in the year an artesian well, the second at Harvey Cedars, was completed at the club-house at Harvey's Point. The location is immediately adjacent to the Harvey Cedars hotel on Long Beach. The work was done by Uriah White, contractor.

The well reached a total depth of 500 feet and draws a copious supply of pure, sparkling water from medium-coarse, water-bearing sands that occupy the entire interval below 420 feet, excepting only a clay parting that occurs between the depths of 463 and 470 feet. The diameter of the well is 4½ inches and the natural flow from the top of the casing, 6 feet above high tide, is 120 gallons a minute. The well was finished with strainer pipe and point from below 420 feet to the bottom.

The water-bearing horizon, at 420 to 500 feet, is the same as that supplying wells at Beach Haven, with a depth of 575 feet, and at Brigantine, where a depth of 793 feet was reached; at Atlantic City, where a depth of about 800 feet is reached by several wells; also at Longport and Ocean City, where a like depth of about 800 feet is attained, and at Sea Isle City, where a boring 854 feet deep has been made. A well at Wildwood is also probably supplied from this horizon at the depth of about 900 feet. Wherever it has been met with this horizon supplies an abundance of most excellent water.

In boring this well a higher water-bearing horizon, 30 feet thick between the depth of 210 and 240 feet, was passed through. This is the same horizon as that supplying a well at the railroad station here, put down some years since to a depth of 240 feet. The supply, however, from the lower horizon is very much greater than from the upper one, while experience here, as at Atlantic City, has abundantly proved that the lower supply is of better quality. Below is the record in detail:

Thickness of Beds (In Feet).		Intervals (In Feet).	
1	Surface sand	0 to 1	Recent.
1	Sedge mud	1 " 2	
8	Beach sand	2 " 10	
1	Old meadow bed	10 " 11	
29	Beach sand	11 " 40	
15	Gray, sandy clay	40 " 55	
20	Yellowish sand, shade of brown sugar	55 " 75	Beacon Hill. (?) Miocene. (?)
5	Coarse sand, almost gravel	75 " 80	
40	Yellowish sand, shade of brown sugar	80 " 120	
44	Gray sand, very clayey	120 " 164	
46	Dark-colored clay	164 " 210	Chesapeake. Miocene. 164 to 415 feet, Diatomaceous.
30	Gray sand, *1st water horizon*	210 " 240	
80	Dark-colored clays, similar to those above	240 " 320	
20	Light, brownish sand	320 " 340	
60	Dark-gray, sandy clay	340 " 400	
20	Dark-brown, sandy clay	400 " 420	
43	Medium-coarse, brownish-gray sand, *2d water horizon*, 2 feet *wood* at the base	420 " 463	
7	Clay, not diatomaceous	463 " 470	
30	Sand, brownish on top, gray at the bottom, *continuation of 2d water horizon*	470 " 500	

Geological Notes.

The upper 55 feet of this boring may be classed as recent. From thence to the depth of 120 feet the sands and gravels are mostly of a yellowish tint, nearly resembling the shade of a good grade of brown sugar. In general appearance these sands and gravels are very suggestive of deposits elsewhere outcropping in the State, which have been named Beacon Hill by Prof. R. D. Salisbury, and which are, at least tentatively, regarded as of Miocene age.

The entire section, however, below 120 feet, is undoubtedly Miocene. Of this lowest division, the interval between 164 and 415 feet is occupied by the great Miocene diatomaceous clay bed of the Atlantic coastal plain, which has been encountered in the boring of a number of wells to the northward as far as Asbury Park, and also on the sinking of all the wells in the State to the southward along the beaches and a greater or less distance inland. It here presents a thickness of 250 feet, all of which, excepting the 30 feet of sand representing the upper water horizon, between the depths of 210 and 240 feet, has been found on careful micro-

scopic examination of specimens of the borings from twenty different depths to contain marine *diatoms*, among which are the usual characteristic forms always elsewhere associated with this bed and which are not found in the diatomaceous beds of a still later age that exist along the coast and nearer the surface.

At Asbury Park this bed has a thickness of but a few feet, but this increases southward till it has a thickness here and beneath Beach Haven of 250 feet, beneath Brigantine of 280 feet, beneath Atlantic City, Longport, Ocean City, of 300 feet and over, and beneath Wildwood, and Sea Isle City, N. J., and Crisfield, Md., of fully 400 feet.

ARTESIAN WELL AT ATLANTIC CITY.

At "The Dennis."—Diameter, 6 inches; depth, 835 feet.

Early in the year Uriah White completed the boring of a well at the Dennis, Atlantic City, N. J. This well is 835 feet in depth, and is supplied from what may be termed the 800-foot horizon at Atlantic City, and which, as is elsewhere noted in this report, also furnishes an abundance of excellent water at Harvey Cedars, Beach Haven, Brigantine, Longport, Ocean City and Sea Isle City, and probably also at Wildwood. The record of this well is practically the same as that published last year for a well at the Brighton, but a few blocks distant. As, however, a full series of specimens was furnished through the co-operative courtesy of Jos. Borton, proprietor of the Dennis, and of Uriah White, the contractor, and F. Brower, the foreman in charge, and as these have been studied very carefully, and also because the more recent labors of other workers on the State survey tend to place the division between the Pleistocene and the Miocene higher than the writer has heretofore done in these well-reports, we here introduce a revised and detailed record, which is the result of such studies:

Specimens.		
Top to 22 feet.	Beach sand, gray	Recent. 83 feet.
22 feet to 55 feet.	Beach sand, slightly darker	
55 " 70 "	Specimen missing.*	
70 " 83 "	Sandy clay, contains *marine diatoms*, recent species; also *sponge spicules*	

* In other wells at Atlantic City at about this depth a yellow gravel with fossiliferous pebbles occurs. Several shallow wells draw water from this gravel.

83	feet to	90	feet	White sand	
90	"	100	"	Clay, no micro-organisms	
100	"	110	"	White sand	
110	"	130	"	White gravel, coarse as cracked hominy	
130	"	155	"	Orange yellow gravel, coarse as cracked hominy	
155	"	165	"	Orange yellow sand, shade of brown sugar	Beacon Hill. (?) Miocene. (?) 162 feet.
165	"	175	"	Orange yellow, coarse sand	
175	"	193	"	Orange yellow, finer sand	
193	"	200	"	White sand	
200	"	201	"	White clay, no micro-organisms	
201	"	220	"	White sand	
220	"	245	"	White sand, with some *lignite*	
		245	"	White sand, with much *lignite*	
245	"	265	"	Gray sand	
265	"	275	"	Gray sand	
275	"	300	"	Gray sand	
300	"	305	"	Clay, no diatoms	Miocene. Not diatomaceous. 125 feet.
305	"	330	"	Gray sand, no micro-organisms	
330	"	350	"	Gray sand, no micro-organisms	
350	"	365	"	Gray sand	
365	"	370	"	Gray sand	
370	"	390	"	Gray sand and clay *marine diatoms*	
390	"	400	"	Gray sand	
400	"	425	"	Clay *marine diatoms* and *sponge spicules*	
425	"	446	"	Clay *marine diatoms*, some comminuted *shell*	
446	"	464	"	Clay marine *diatoms* and *sponge spicules*	
464	"	482	"	Clay *marine diatoms* and *sponge spicules*	
482	"	500	"	Clay sponge *spicules* and a *few diatoms*	
500	"	519	"	Clay *marine diatoms* and *sponge spicules*	Miocene. Diatomaceous. 360 feet.
519	"	539	"	Clay *marine diatoms* and *sponge spicules*	
539	"	559	"	Clay, sandy, *diatoms*	
559	"	579	"	Clay, sandy, *diatoms*, plenty	
579	"	599	"	Clay, sandy, *diatoms*	
599	"	618	"	Clay *sponge spicules* and *diatoms*	
618	"	637	"	Clay *diatoms* and *sponge spicules*	
637	"	656	"	Clay *diatoms* and *sponge spicules*	
656	"	673	"	Clay *diatoms* and *sponge spicules*	
673	"	690	"	Clay, a few *diatoms*	
690	"	710	"	Sand and *shells* and a little clay, very few *diatoms*	
710	"	730	"	Sand	

730 feet to 750 feet	Sandy clay, no micro-organisms........	Miocene. Not diatomaceous. 105 feet.
750 " 760 "	Sand and clay, no micro-organisms...	
760 " 775 "	Sand and clay, no micro-organisms...	
775 " 835 "	Sand, brownish, *water-bearing*...........	

ARTESIAN WELLS AT ATLANTIC CITY.

At "The St. Charles"—Diameter, 6 inches; depth, 822 feet.
At "The Rudolf"—Diameter, 6 inches; depth, 841 feet.

After the completion of the well just recorded at the Dennis, two other wells were put down at Atlantic City by the same contractor, Uriah White, one at the St. Charles and the other at the Rudolf. The well at the St. Charles has a depth of 822 feet, and that at the Rudolf of 841 feet.

To introduce the details respecting the strata penetrated would be but to duplicate the record already introduced for the Dennis, so constant and similar are the beds. The water-bearing horizon reached is the same as that furnishing the Brighton, the Dennis, and some of the wells on the meadows, viz., the 800-foot Atlantic City horizon, which we have so named, because that is its depth in wells bored on the meadows and which are about one mile farther back on the dip of the beds.

ARTESIAN WELL AT ATLANTIC CITY, AT "THE HADDON" HOUSE.

Elevation, 10 feet or more; diameter, 6 inches; depth, 840 feet.

After the close of the summer season Uriah White sunk a six-inch well at the Haddon House to the depth of 840 feet, the lower fifty feet of which was cased with a strainer-tube. The well draws from the great Miocene water horizon, which we have designated in this report the 800-foot Atlantic City horizon, and which occurs in this well at the depths of 790 to 840 feet, the upper twenty feet of which interval is a brownish sand, and the lower thirty feet a gray sand. Minor water horizons were met at the depths of 540, 700 and 750 feet, which were not utilized. The top of the great Miocene diatomaceous clay bed was found at the depth of 410 feet. Molluscan fossils were noticeable at 700 feet. The well yields an abundance of water by pumping.

Its elevation is, however, greater than that of many of the wells at Atlantic City, in consequence of which the natural overflow is not as great, being but about 30 gallons a minute.

THIRD ARTESIAN WELL AT OCEAN CITY.

Elevation, 5 feet; diameter 8 inches; depth, 821 feet.

Just previous to the commencement of the summer season Uriah White completed the boring of an artesian well at Ocean City. This is the third well at this place. The first was noted in the Annual Report for 1892, and the second in that for 1893. The first well draws from sands next below the depth of 720 feet, the second from sands next below the depth of *about* 750, as does also the well now under consideration. With reference, however, to the present well, it may be more accurately stated that this water-bearing sand extends from the depth of 746 feet to that of 821 feet. This horizon may be conveniently designated the 800-foot horizon of Atlantic City, that being an average depth there for the wells that draw from it. Its top is there met with under the meadows at about 750 feet, while beneath the beach front its base has not been entirely penetrated at the depth of 850 feet.

This horizon also furnishes wells at Harvey Cedars, Beach Haven, Brigantine, Atlantic City, Longport and Sea Isle City, at all which localities a great abundance of water of excellent quality is obtained therefrom.

Records of strata at Ocean City were inserted in the two previously-published records noted above. But few samples, however, of the first 300 feet were then furnished, and the records for that interval were quite general. A set of borings of the entire well, including an unusual number of specimens of the first 300 feet, were carefully saved by Thos. Scanlin, foreman in charge of the work, and presented to the survey. This enables us to present a more detailed description of the upper or superficial beds. We here insert a revised record of strata. Below 318 feet, however, it is essentially the same as has been heretofore published:

Beach sand to			**20 feet.**		**Recent.**
Slightly clayey near the base.					
Gray sand	**20 feet to**		**30**	**"**	
Gray sand, considerable comminuted shell*	**30**	**"**	**40**	**"**	
Gray sand, slightly clayey	**40**	**"**	**45**	**"**	
Gray sand, lighter in color, very slightly brownish	**45**	**"**	**65**	**"**	
Coarse, gravelly sand, some shell*	**65**	**"**	**75**	**"**	
Gray sand, finer	**75**	**"**	**80**	**"**	**Beacon Hill (?) Miocene (?)**
Coarse, sandy gravel, coarser than 65 to 75	**80**	**"**	**85**	**"**	
Fine gray sand	**85**	**"**	**100**	**"**	
Coarse pebbles and tough clay	**100**	**"**	**117**	**"**	
The pebbles are as large as hickory nuts and walnuts and consist of white quartz and white and black cherts, the chert containing fossils, probably either Silurian or Devonian. No *micro-organisms* were found in the clay.					
Sand, shade of brown sugar	**117**	**"**	**120**	**"**	
Sand, darker and clayey.	**120**	**"**	**130**	**"**	
Sand, shade of brown sugar again	**130**	**"**	**160**	**"**	
Sand, again darker and clayey	**160**	**"**	**165**	**"**	
Sand, shade of brown sugar	**165**	**"**	**200**	**"**	
Dark brown sand	**200**	**"**	**240**	**"**	

*The specimens of borings at 40, 45 and 75 feet showed small shells, much broken up by the drill. Prof. H A. Pilsbury, Conservator of Conchological Collections at the Academy of Natural Sciences, Philadelphia, identified *Columbella avara, Say; Gemma gemma, Totten; Nassa trivitatta, Say;* and *Anomia glabra D'Orbigny*. These are recent species, such as are now living. In a very clayey sand, marked from near the top of the well, and which probably was from within the same interval, were found sponge spicules and marine diatoms, among them *Triceratium favus, Ehrb.*, a form now living and also characteristic of recent fossil deposits, but which is not found in the Miocene.

Dark sand, clayey	240	feet to	278	feet.	Miocene, more or less *diatomaceous*, especially so below 385 feet.
Dark sandy clay	278	"	300	"	
Dark tough clay, with a few *diatoms*	300	"	318	"	
Sand, with water	318	"	334	"	
Bluish sandy *diatomaceous* clay, with small shells, among them *Turritella plebeia*, Say	334	"	366	"	
Sand, with water	366	"	371	"	
Bluish clay, with shells, among them *Turritella plebeia* quite plentiful	371	"	385	"	
Diatomaceous clay	385	"	492	"	
Specimens were taken at the depths of 385, 395, 420, 435, 445, 450, 470 and 492, and all showed marine *diatoms* under the microscope.					
Sand	492	"	511	"	
Sand, fine gravel and comminuted shell. *Diatoms* in clay. *Water* in sand. Overflow, 7 gallons a minute	511	"	528	"	
Bluish sandy clay, *diatomaceous*	528	"	600	"	
Brownish hard sandy clay, with shell, *diatomaceous*	600	"	658	"	
Specimens of clays from the depths of 520, 525, 550, 560, 570, 585, 590, 595, 600, 606, 610, 615, 630, 635, 650 and 655, all contained marine diatoms.					
Rock, 18 inches, say	658	"	660	"	Miocene. Not diatomaceous.
Gray sand, comminuted shell in the first five feet	660	"	675	"	
Clayey sand, *diatoms*	675	"	680	"	
Fine clay, hard, no diatoms, plenty of shells of, &c	680	"	685	"	
Sand, with water	685	"	690	"	
Fine gravel, sand, shell and three clay seams, no diatoms	690	"	716	"	
Alternations of clay, gravel, sand, shell and thin clay seams, no diatoms; water at 720 feet; flow, 25 gallons a minute	716	"	736	"	
Brownish sand, with lignite	736	"	746	"	
Coarse brown sand, with water, 140 gallons a minute	746	"	821	"	

BORED WELL AT CLAYTON, DELAWARE.

Elevation, 40 feet (?); depth, 152 feet.
Notes on the stratigraphical position of Heliopelta.*

Some years since a boring was made at Clayton, Delaware, for the Baltimore and Delaware Bay railroad, to a depth of 150 feet and was then abandoned before reaching any of the water horizons that exist lower down. Upon learning that surface and driven wells in close proximity and at about the same level find water at depths of 35, 60 and 85 feet, the railroad company subsequently had a well put down to the depth of 35 feet which has answered for their supply.

Stratigraphically this boring is especially interesting and it is, therefore, placed on record. This well was cased to the depth of 102 feet; the 50 feet below this penetrated a blue clay** so stiff that the walls remained open without casing. By sounding, the writer obtained some of this blue clay, and, upon microscopic examination, it was found to contain marine diatoms, among them being *Heliopelta* a form characteristically confined to the Atlantic Miocene diatomaceous beds and to the basal portion thereof only.

To the northward this form occurs in the clay that overlies the Miocene shell marl, near Shiloh, N. J., and to the southward it has been found in Miocene clay dredged up at the steamboat landing at Claiborne, Md., on the eastern shore of the Chesapeake. Its presence at both the last-named localities was learned by a microscopic examination of clays that had been personally collected by the writer in the field.

Heliopelta also occurs at Asbury Park in Miocene clay that overlies Eocene marl, the top of which is found in the well-borings at the depth of 80 feet. Heliopelta similarly occurs over Eocene marl at outcrops along the Patuxent river, near Nottingham, Md. It has also been found in similar position with reference to the Eocene in a well-boring at Wildwood, N. J., at the depth of 1,040 feet, and in another boring at Crisfield, Md., at the depth of 790 feet.

* Technically *Actinoptychus Heliopelta, Grunow* or, as formerly classified, Heliopelta Ehrenbergii. It is a diatom visible only by the aid of a microscope. Illustrations, magnified 200 diameters, occur on plate VI, page 472 of the annual report for 1894.

** This has been described to the writer as "marsh clay, gray in color," which is its appearance when dry. It has also been described as sticky and as soapy in character.

In all the localities above named, this diatom manifestly occurs near the base of the Miocene, or, as the geologists of the United States survey would say, near the base of the *Chesapeake Miocene.* The writer has made very many careful examinations of mounts of diatoms prepared from numerous cleanings made from Miocene clays above the basal beds, and which had been obtained from well-borings ranging in location from Barnegat, N. J., to Old Point Comfort, Va., and has always failed to find this form stratigraphically higher. Its occurrence at any locality, therefore, marks a definite geological horizon. This exact species has not, as yet, been found elsewhere in the world.

ARTESIAN WELL NO. 3, AT SEA ISLE CITY.

**Elevation, 3 feet (?); diameter, 6 inches; depth, 854 feet.
Water rises 14 feet above the surface; overflows at the surface, 160 gallons a minute.**

In the spring of the present year, Kisner & Bennett finished the boring of a successful well at Sea Isle City. The total depth reached was 854 feet. Water horizons were found between the depths of 785 and 800 feet, and again between the depths of 818 and 854 feet. The well was finished with a strainer, so arranged as to draw from both these water-yielding strata. The water rose 14 feet above the surface, and has a natural flow about one foot above the surface, of 160 gallons a minute.

The contractors courteously furnished a full set of specimens of the strata, and an accurate detailed memorandum of the same. After careful study of these and comparison of the same, the writer presents the following record:

Feet.				
4.	Beach sand	0 ft.	to	4 ft.
6.	Meadow mud, the same as that which can be seen outcropping on the beach at low water	4	"	10 "
26.	Dark muddy sand	10	"	36 "
113.	Coarse white sand	36	"	48 "
	Coarse white sand, with some gravel	48	"	149 "
	Wood and bark in the upper 40 feet; wood bored by teredo; scarcely lignitized.			

Feet.		Depth.	
29.	Blue clay, very fine	149 ft. to 157 ft.	A few sponge spicules.
	Blue clay, sandy	157 " 172 "	A few sponge spicules.
	Light-colored clay	172 " 178 "	A few sponge spicules.
100.	Gravel and coarse sand. *Water* rose to surface below 261 feet.	178 " 278 "	
31.	Muddy sand	278 " 309 "	
33.	Dark-blue clay	309 " 342 "	Diatoms, sponge spicules and *cocoliths*.
28.	Fine quicksand. Water rose to the surface horizon, the same as that supplying the Continental Hotel and Electric Light Works wells.	342 " 370 "	A few sponge spicules.
76.	Tough bluish-gray clay	370 " 446 "	A few sponge spicules.
32.	Tough bluish-gray clay. Lighter in shade.	446 " 478 "	Diatoms.
2.	Rock (2 ft. 6 in.), say	478 " 480 "	
10.	Sand and shell	480 " 490 "	
34.	Clay and shell	490 " 524 "	Diatoms and sponge spicules.
6.	Quicksand	524 " 530 "	
12.	Dark-brown clay	530 " 542 "	Sponge spicules and diatoms.
38.	Greenish marly sand	542 " 580 "	
40.	Greenish clay	580 " 620 "	Diatoms, *Actinocychus*, &c.
82.	Dark-brownish clay	620 " 638 "	Diatoms, *Actinoptychus*, &c.
	Dark-brownish clay	638 " 657 "	Diatoms.
	Dark-brownish clay	657 " 677 "	A few diatoms.
	Dark-brownish clay, sandy,	677 " 702 "	Diatoms, a few.
79.	Dark sand, clayey	702 " 707 "	
	Dark-brown clay	707 " 713 "	No micro-organisms.
	Brownish muddy sand	713 " 730 "	No micro-organisms.
	Brownish fine sand	730 " 749 "	
	Brownish sand	749 " 768 "	
	Sand, muddy	768 " 781 "	
73.	Sand, *water-bearing*	781 " 800 "	
	Muddy sand	800 " 818 "	
	Coarse sand, *water bearing*	818 " 833 "	
	Fine sand, *water-bearing*	833 " 849 "	
	Brown sand, *water-bearing*	849 " 854 "	

The water horizon utilized by this well is the equivalent of what, for convenience, may be called the 800-foot horizon at Atlantic City. A higher horizon was observed, while boring, between the depths of 342 and 370 feet. This is the same as that which supplies two wells formerly put down at this locality, one of which, at the Continental hotel, was noted, in the report for 1888, as having reached a depth of 380 feet, and the other, at the Electric Light works, was noted, in the report for 1890, as having

attained a depth of 464 feet, the flow, however, being stated to come from 350 to 390 feet.

It will be noticed that the great Miocene diatom clay-bed of the Atlantic coastal plain was here again pierced, as has been the case with all wells in Miocene strata along the New Jersey coast south of Barnegat.

Diatoms were found in every clay specimen, twenty in number, from the depth of 309 to that of 702 feet, a thickness of nearly 400 feet. The same thickness has been observed by the writer at Wildwood, N. J., and at Crisfield, Md.

ARTESIAN WELL NO. 4, AT MILFORD, DELAWARE.

Elevation, 5 feet; diameter, 10 inches; depth 244 feet.
Correlation with wells Nos. 1, 2 and 3, noted in the Annual Report for 1891.
Three water horizons.

First horizon at the depth of	30 feet
Second horizon between the depths of	145 feet and 160 "
Third horizon between the depths of	207 " " 228 "

J. H. K. Shanahan, of Easton, Md., reports having bored a well the past year at Milford, Delaware, to the depth of 244 feet, obtaining a good quality and quantity of water from between the depths of 207 and 228 feet. This is the fourth well that has been put down at Milford for the Light and Water Commission there. The three former wells were reported in detail and illustrated in the annual report for 1891, pages 227 to 230.

The wells are all situated on the south bank of the Mispillion creek, near the head of tidewater, which here rises and falls about 4 feet. The ground rises gradually from the stream, the area occupied by the water plant being from 2 to 5 feet above high water.

Certain factors common to all these wells may be tabulated thus:

Well.	Size of Casing.	Depth.	Elevation of Surface.	Rise of Water.	Pumping Capacity Per Hour.
No. 1,	6 inches	160 feet	5 feet	2 feet above surface	4,000 gallons.
No. 2,	6 "	150 "	2 "	5 "	4,000 "
No. 3,	6 "	34 "	5 "	Just to surface	3,000 "
No. 4,	10 "	244 "	— "	Large overflow when not pumping.	

The illustrated record of 1891 is here reproduced as far as to the depth then attained of 160 feet, below which we add the record for the remainder of the section as revealed by this (No. 4) well:

THICKNESS.	1.	3. BEDS.	NOTES MADE BY JAMES H. BELL.
11'	11'	Gravel.	
14'	25'	Blue-Gray Clay.	
19'	44'	Fine Gray Sand. *Water* flows to surface.	From about 10 feet to 60 feet, fine sand mixed with lumps of blue clay, which gave the water a decided dirty color.
16'	60'	Blue-Gray Clay.	
8'	68'	Fine Gray Sand.	
5'	73'	Blue Clay.	At 65 and 80 feet, wood, in pieces $\frac{1}{16}$ to $\frac{1}{2}$ inch in size.
17'	90'	Fine Gray Sand, with woody particles.	At 85 feet, clean gravel, broken shells and fragments of thin stone.
28'	118'	Fine Gray Sand, containing shells.	At 110 feet, very fine sand.
3'	121'	Blue Clay.	At 120 feet, very small snail and broken clam shells, then mostly very fine sand to greatest depth of 160 feet.
16'	137'	Fine Gray Sand.	
3'	140'	Greenish Clay.	At intervals all the way down from 100 feet, fractured clam and snail shells, but all very minute, and except in about a dozen instances requiring a magnifying glass to determine their character, but with this there was no mistaking what they were.
20'	160'	Fine Blue-Gray Sand. *Water* flows two feet above surface.	
		CONTINUATION OF WELL NO. 4.	NOTES BY THE AUTHOR.
47'	207'	Clay, Diatomaceous.	
21'	228'	Gravel, Shell, Sand and *Water*.	*Melanopsis*, &c. St. Mary's Fauna. Miocene.
16'	244'	Clay Diatomaceous.	

WELL-SECTION, MILFORD, DEL.

The wells were drilled by the hydraulic process. Wells No. 1 and No. 2 draw from the same stratum, and were each cased to the depth of about 141 feet. No. 1 was continued about 20 feet and No. 2 about 10 feet further and a considerable quantity of sand pumped out and replaced with clean, pebbly gravel, to keep back the sand and allow a free flow of water.

Well No. 4 obtains its supply from between the depths of 207 and 228 feet.

The process employed in boring ground the shells noted in the section so thoroughly that only small fragments were obtainable, but by sifting these from a considerable quantity of material left near the wells after their completion, and then carefully looking over the fragments, the following genera from above the depth of 160 feet were recognized: *Arca*, *Astarte*, *Natica* and two forms of *Turritella*,* the latter being specifically the same as two forms that occur so abundantly in the shell marls near Shiloh, N. J.

Between the depths of 207 and 228 feet is a *water-bearing* stratum 21 feet thick, consisting of a mixture of sand, gravel and fossil shells. Among the shells picked out from the borings at the depth of 225 feet are the following: *Melanopsis Marylandica*, *Astarte*, *Corbula*, *Trittia*, *Pecten*. There was also found *Balanus proteus*, a barnacle, and *Otolithus* (*scianidarum*) *elongatus*, *Koken*, the latter the ear-bone of a fish allied to the present weakfish and Cape May goody.

The *Otolithus* is identically the same form as was found in the well-borings at Wildwood, though occuring here stratigraphically many feet higher.

The shell fauna indicates the upper or St. Mary's Miocene. The *Melanopsis* has heretofore been found at Wildwood, depth 328 feet, also in borings at Cape May and in outcrops at St. Mary's, Maryland.

The water horizons—140 to 160 feet and 207 to 228 feet—are intimately associated with the upper portion of the great Atlantic Miocene diatom bed.

These facts respecting the shell fauna show that the strata in the wells at the two localities enter beds belonging to the same geological period, *i. e.*, the Miocene, and determine their position in these wells to be, not in the superficial horizontal gravels and

*Turritella Cumberlandia, Conrad. Turritella æquestriata, Conrad.

sands, but within the underlying series of clays and their interbedded sands, and which are known to have a slight dip to the southeast.

Considering the northeast and southwest strike of the Miocene strata along the Atlantic seaboard, these water horizons should be found in extreme southern New Jersey. If the dip for these beds near Delaware bay be the same as that indicated by the facts connected with the wells along the section from Weymouth to Atlantic City—that is, about 25 feet per mile—then the 140 to 160-foot horizon at Milford must be nearly equivalent to that of 350 to 390 feet supplying the electric light company's well at Sea Isle City, N. J. (See Annual Report for 1890, page 272.)

It should also be looked for at Cape May at a depth of 475 to 525 feet. A well put down some years since at Cape May Point and abandoned at the depth of about 450 feet, was probably discontinued not far above this water horizon.

Sec. 3.—Well in Recent Strata.

TEST-BORINGS AT SANDY HOOK.

Some test-borings, to the depth of 200 feet, were made at Fort Hancock, Sandy Hook, by P. H. & J. Conlin, who furnished a set of specimens, from which the following record is made:

	Depth of specimens.
Coarse white sand	at 30 feet.
White sand and fine gravel	" 55 "
Gray sand and gravel; some fragments of *shell*, evidently *clam*	" 73 "
Fine yellowish-gray sand	" 78 "
Coarser yellowish-gray sand	" 107 "
Medium yellowish-gray sand	" 115 "
Greenish, fine, clayey sand, with *sponge spicules* and *diatoms*	" 125 "
Greenish clay, with diatoms and *Foraminafera*, and small fragments of *molluscan shells*	at 135 to 145 "
Gray sand	at 155 "
Brownish-gray sand	" 165 "
Brownish, muddy sand	" 185 "
Brownish-yellow sand	" 200 "

Beneath the clay noted at the depth of 145 feet, we are informed there was liberated quite a quantity of gas, which was exhausted after three days. See, also, page 133.

II.

Bored Wells, Mostly in Northern New Jersey.

OUTLINE.

Introduction.

Sec. 1.—Reported by P. H. & J. Conlin.

Newark, 5 wells.
Harrison, 2 wells.
Reeseville.
Fort Lee.
Jersey City, 2 wells.
Plainfield.
South Plainfield.
Passaic.
Bayonne.
Sandy Hook.
League Island, Pa., U. S. Navy Yard.
Camden.
New York City—
  Columbia University.
  Tenth Ave. and 50th St.
  Tenth Ave. and 128th St.
  Waldorf Hotel.
East New York.
Connecticut.
Norfolk (Va.).

Sec. 2.—Reported by Stotthoff Bros.

Lake Hopatcong.
Morristown.
Hamburg.
Franklin.
Augusta.
Deckertown, 2 wells.
Newton, 3 wells.
Stillwater.
Marksboro, 2 wells.
Phillipsburg.
Whittaker.
Carpenterville.
Paterson.
Lake View, 5 wells.
Ridgewood.
Passaic, 12 wells.
Somerset.
Belmont.
Arlington.
Roselle.
Plainfield.
Lebanon.
Hamden.
Flemington, 5 wells.
Three Bridges.
Ringoes.
Frenchtown.
Lambertville.
Hopewell.
High Bridge.
Lawrenceville.
Ewing.
Yardley (Pa.), 4 wells.
Rauches (Pa.).
Yardville.
Delaware.
Pleasantville (N. Y.).
Cornwells (Pa.).
Torresdale (Pa.).

Sec. 3.—Reported by W. R. Osborne.

Port Reading, 3 wells.
Woodbridge.
Metuchen, 3 wells.
Perth Amboy, 2 wells.
New Brunswick.
Ford's Corners, 2 wells.
Carteret, 2 wells.
New Castle (Del.), 3 wells.
Hare's Corners (Del.).

Sec. 4.—Reported by others.

Metuchen.

INTRODUCTION.

The following wells are mostly north of a line joining Amboy and Trenton. There are included a few wells on the Pennsylvania side of the Delaware river and a few in New York city and state. These are introduced because of their intimate association with the geological formations in New Jersey which, in fact, they help to explain. Excepting the well noticed in section 4 the data respecting them has been furnished by three well-contractors, viz., P. H. & J. Conlin, Stotthoff Bros., and W. R. Osborne.

Sec. 1.—Bored Wells, reported by P. H. & J. Conlin.

P. H. & J. Conlin write as follows respecting wells put down by them the past two years. We copy their letter verbatim:

WELLS IN NEWARK.

"We put down for the Citizens' Gaslight Co., near the Harrison bridge, a well about 600 feet deep; rock was met at 35 feet, then red shale at a depth of 90 feet, when Belleville sandstone was struck.

"We had to case off the water met in soft shale on account of the percolation of the gas from the holders impregnating the surface-water and the water found in red shale. When we were down to the lower vein the yield was 50 gallons of water per minute.

"A six-inch well for Unger Bros., Beecher street near Clinton avenue, 300 feet. Clay and quicksand to 80 feet, then red rock. The well produced 35 gallons per minute.

"Well for Weingarten Bros., High street near the incline plane of Morris canal. All through soft shale to a depth of 200 feet; well produced 30 gallons per minute.

"Well for the Newark Jewelry Co., on N. J. R. R. avenue, produces a good supply of water.

"We are sinking a well at present for P. Louentrout on the hill. We are down about 400 feet through red shale; we have a good supply of water. The well is ten inches in diameter.

WELLS AT HARRISON, OPPOSITE NEWARK.

"We sunk three wells for the Benj. Atha & Illingsworth steel works, at Harrison, N. J. They are 80 feet deep and yield 85 gallons of water per minute; the quality of the water is very good; it is in sand and in gravel where we found the water.

"A short distance from the steel works we made a test for the General Electric Co., 80 feet. We met nearly all quicksand, quite a different strata and no gravel; the two points are not over 500 feet apart.

WELL AT ROSEVILLE (NEWARK).

"At Roseville (Newark) we sunk a well for the St. Mary Cemetery, 120 feet in red shale, which yielded an abundant supply of good water.

"In nearly all the Newark wells the strata is about the same, but the level of the water is falling and is now about the tide-level, showing that the supply comes from nearly the same strata.

WELL NEAR FORT LEE.

"Near Fort Lee, for the Bergen County Traction Co., we sunk a well and found red shale under trap-rock and got 30 gallons per minute at 150 feet.

WELLS AT JERSEY CITY.

"In Jersey City, near the Pennsylvania railroad station, we sunk a well for Colgate & Co., through fine sand to 35 feet, where we met gneiss rock and mica. We went to a depth of 1,500 feet. Well yields but fifteen gallons per minute. At other points near there we put in wells, and where we found red sandstone under trap or gray rock we found water.

"We have put down a second well in Jersey City for the Jersey City Paper Company. The formation met with was very fine sand; we found a good supply at 90 feet; we encountered no rock.

WELLS AT PLAINFIELD.

"At the Plainfield Gas and Electric Company, near the Central railroad, we put down two wells for condensing purposes; their combined yield is about 300 gallons per minute; their depth, at present, 400 feet, and we expect to go deeper. There is 15 feet of quicksand at surface, and all the wells are in red shale.

WELLS AT SOUTH PLAINFIELD.

"We sunk three 12-inch wells at South Plainfield, near the Lehigh Valley depot; each of them flows about 150 gallons per minute, and produces, on pumping, 500 gallons per minute. They are through red shale, and each 200 feet deep.

WELL AT PASSAIC.

"We put down a 12-inch well 303 feet, for Reid & Barry, on the Passaic bank, 80 feet to rock; the strata above rock is quicksand and some gravel, then we met red shale. Well tested 500 gallons per minute.

WELL AT BAYONNE.

"For the Bayonne Chemical Company, at Bayonne, N. J., we sank a six-inch well, entered red shale and got good water. The well is not finished. This well is peculiar for the reason that the

Standard Oil Company sank several wells on the adjoining property, where they struck trap-rock, which shows that the strata at the lower end of Bayonne runs very unevenly.

WELL AT SANDY HOOK.*

"The most noticeable of the wells we have put down this year was a test-hole at Fort Hancock, Sandy Hook. The top formation is sand, like nearly all on the coast-line of New Jersey. At a depth of 150 feet, underneath a bed of greenish-blue clay, we encountered a vein of sand and gravel, and a strong vein of 'carbonic acid gas,' that must have had a pressure of over 200 pounds to the square inch. 'When it was first struck it shot the sand and water in the air to a height of 75 to 100 feet, but gradually fell off, and in three days exhausted itself after throwing out several hundred yards of sand and dirt with water.'

WELL AT LEAGUE ISLAND, PA., AT PHILADELPHIA NAVY YARD.†

"We are drilling a ten-inch well at the League Island Navy Yard. We are down about 450 feet. It was sand and clay to 230 feet, then we encountered soft gneiss rock. We are still working at it.

TEST WELL AT CAMDEN.

"We made several tests on the site of the new armory at Camden, for the foundation. We found sand, with water-bearing strata, all the way from surface to a depth of 200 feet. We encountered no rock.

WELLS IN NEW YORK CITY, N. Y.

"We put down several wells in New York City. One at Columbia College, Fiftieth street, near Tenth avenue; one for Cushman's bakery, near Tenth avenue, on Fiftieth street. In both wells we passed through gray gneiss and mica. We found a poor supply in both wells, while for D. G. Youngling's Brewing

* For a detailed record of this well, see page 180.
† For a detailed record of this well see page 114.

Co., at One Hundred and Twenty-eighth street and Tenth avenue, at a depth of 135 feet in gravel, we found 75 gallons of water of excellent quality. These wells have all been sunk since our last report.

"We drilled several 16-inch holes at the New Waldorf Hotel, in New York, and found considerable water in the gneiss and mica formations.

WELLS AT EAST NEW YORK.

"The greatest yield and the best quality of water we got at East New York for the Long Island Water Supply Co., where it is all gravel and coarse sand. The yield was about two and a half millions gallons per day from six 8-inch wells that run from 65 to 95 feet deep.

WELLS IN CONNECTICUT.

"We have put down several wells in Connecticut. The deepest one we sunk was 1,500 feet, at Noroton. The rock was very hard, and no water of any account was found.

TEST BORINGS AT NORFOLK, VA.

"Have made tests to a depth of 120 feet, and found the formation nearly similar to that found at Atlantic City and at Lewes, Del."

Sec. 2—Bored Wells, reported by Stotthoff Bros.

The following seventy-one wells are reported by Stotthoff Bros. as having been drilled by them the past two years in New Jersey and parts adjacent.

LAKE HOPATCONG, AT H. W. CORTRIGHT'S.

Earth	6 feet.
Gray rock, very irregular and full of hard and soft streaks	94 "
Depth	100 "

Water, 2 gallons per minute.

MORRISTOWN, TWO MILES WEST OF THE TOWN. FOR L. C. GILLESPIE.

Started in bottom of old well; depth	67 feet.
Hard granite; very few changes in character, and not much water	137 "
Depth	204 feet.

HAMBURG, SUSSEX COUNTY, FOR REEVES HARDEN.

Blue clay	70 feet.
Quicksand	50 "
Fine gray sand, mixed with clay	15 "
Depth	135 "

Water rises within 14 feet of the surface; yield, 20 gallons a minute.

FRANKLIN, SUSSEX COUNTY, FOR JAMES MAY.

Limestone	35 feet.

AUGUSTA, SUSSEX COUNTY, AT GEORGE ROE'S.

Earth and gravel	63 feet.
Slate rock	187 "
Depth	250 "

Water, about 15 gallons per hour.

DECKERTOWN, AT SUSSEX COUNTY CONDENSED MILK COMPANY'S.

Earth and gravel	22 feet.
Slate rock	12 "
Depth	34 "

DECKERTOWN, AT DR. JOHN MOORE'S.

Earth	6 feet.
Slate rock	59 "
Depth	65 "

NEWTON, AT JOSEPH HUNT'S.

Earth	7 feet.
Slate rock	49 "
Depth	56 "

Water, 15 gallons per hour.

NEWTON, AT WM. M'CAIN'S.

This well is located near Newton.

Earth	3	feet.
Slate rock	136	"
Depth	139	"

Water, 25 gallons per minute.

NEWTON, AT WM. LATAMORE'S.

Earth	12	feet.
Slate rock.	65	"
Depth	77	"

Found water in the rock, 5 gallons per minute.

STILLWATER, SUSSEX COUNTY, AT LEWIS ROY'S.

Clay and gravel	23	feet.
Limestone rock	3	"
Depth	26	"

Water, 20 gallons per minute.

MARKSBORO, SUSSEX COUNTY.

This well is located at Yellow Frame Church, near Marksboro.

Clay, gravel and bowlders	67	feet.
Slate rock	13	"
Depth	80	"

Water, 6 gallons per minute.

MARKSBORO, SUSSEX COUNTY.

Sand and gravel	20	feet.
Limestone rock	7	"
Gray rock on the bottom	2	"
Depth	29	"

Water, 20 gallons a minute.

PHILLIPSBURG, AT PORTLAND VULCANITE CEMENT COMPANY'S.

Earth and gravel	30	feet.
Cement rock (used in making cement)	247	"
Depth	277	"

WHITTAKER, TWO MILES EAST OF PHILLIPSBURG.

Very open limestone, full of pockets; depth .... 99 feet.
Twelve feet of water in the bottom of the well; 9 gallons per minute.

CARPENTERVILLE, FOR TWINING & LARGE, QUARRY.

Limestone	170 feet.
Cement rock, same as at Whittaker Cement Company	20 "
Limestone	2 "
Depth	192 "

Got the water at the lower seam, between the cement and the limestone.

PATERSON, AT HENRY HOBSON'S.

Earth	5 feet.
Red sandstone rock	85 "
Depth	90 "

Water, 20 gallons a minute.

LAKE VIEW.

Earth	8 feet.
Red sandstone	70 "
Depth	78 "

Water, 10 gallons per minute.

LAKE VIEW, AT DAVID SWEENY'S.

Earth	10 feet.
Red sandstone rock	40 "
Depth	50 "

Water, 15 gallons per minute.

LAKE VIEW, AT JOHN HAND'S.

Earth and gravel	15 feet.
Red sandstone rock	84 "
Depth	99 "

Water, 15 gallons per minute.

LAKE VIEW, AT H. B. GRAVATT'S.

Earth and gravel	17 feet.
Red sandstone rock	83 "
Depth	100 "

Water, 10 gallons per minute.

LAKE VIEW, AT GEORGE EVERITT'S.

Sand and gravel	45 feet.
Red sandstone rock	85 "
Depth	130 "

Water, 6 gallons per minute.

RIDGEWOOD, FOUR MILES ABOVE PATERSON, FOR JAMES WHARTON.

Sand	17 feet.
Red sandstone	66 "
Depth	83 "

Water rises within 30 feet of the surface; yield, 10 gallons a minute.

PASSAIC, AT W. H. ANGLEMAN'S.

Earth	24 feet.
Gravel	40 "
Red sandstone rock	20 "
Depth	84 "

Water, 20 gallons a minute.

PASSAIC, AT HENRY RODEL'S.

Sand and gravel	90 feet.
Red sandstone rock	10 "
Depth	100 "

Water, 25 gallons per minute.

PASSAIC, AT D. J. DOW'S.

Earth and gravel	38 feet.
Red sandstone rock	32 "
Depth	70 "

PASSAIC, AT NORTH BOTANY WORSTED MILLS.

Sand and clay	93 feet.
Red sandstone	7 "
Depth	100 "

PASSAIC, AT PASSAIC BEEF COMPANY'S.

Red sandstone surface, to	171 feet.

Water rises within 17 feet of the surface; yield, 25 gallons a minute.

PASSAIC, FOR RICHARD KIPP.

Coarse sand	51 feet.
Red sandstone	50 "
Depth	101 "

Water rises within 10 feet of the surface; 25 gallons per minute.

PASSAIC, ON BELMONT HILL, NORTHEAST OF THE TOWN.

Three wells, within a radius of one-quarter of a mile.

No. 1:

Earth	10 feet.
Red standstone	65 "
Depth	75 "

No. 2:

Earth	22 feet.
Red sandstone	47 "
Depth	69 "

No. 3:

Earth	18 feet.
Red sandstone	22 "
Depth	40 "

All are good wells for house use.

PASSAIC, AT ELECTRIC LIGHT COMPANY'S PLANT.

Sand and gravel	20 feet.
Red sandstone rock	105 "
Depth	125 "

This well will give, at 25 feet from the surface, 375 gallons of water per minute.

PASSAIC, AT BOTANY WORSTED MILLS.

Fine sand and gravel	100 feet.
Red sandstone rock	100 "
Depth	200 "

Water, 3 gallons per minute.

PASSAIC, AT JOHN GRAY'S.

Earth	12 feet.
Red sandstone rock	43 "
Depth	55 "

Water, 5 gallons per minute.

SOMERSET, TWO MILES SOUTH OF PASSAIC, FOR J. AGRAMONTE.

Earth	11 feet.
Red sandstone	40 "
Depth	51 "

BELMONT, BERGEN COUNTY, AT BOTANY WORSTED MILLS.

Earth and gravel	30 feet.
Red sandstone	51 "
Depth	81 "

ARLINGTON, AT A. W. SCHULER'S.

Sand and gravel	42 feet.
Red sandstone rock	10 "
Depth	52 "

Water, 10 gallons a minute.

ROSELLE, AT J. H. CHILVER'S.

Earth	10 feet.
Red shale rock	107 "
Depth	117 "

Water, 15 gallons a minute.

PLAINFIELD.

Earth and gravel	65 feet.
Red shale rock	35 "
Depth	100 "

Water, 15 gallons a minute.

LEBANON, HUNTERDON COUNTY, FOR A. L. RAMAY.

Earth and clay	53 feet.
Soft, crumbling rock, resembling gray rock	12 "
Depth	65 "

HAMDEN, HUNTERDON COUNTY.

Red shale	51 feet.

FLEMINGTON, AT E. W. BARNES'.

This well is located on a hill one mile west of the town, on the change between the red shale and the blue rock.

Depth	120 feet.

Water, 20 gallons per minute.

FLEMINGTON, AT ELECTRIC LIGHT COMPANY'S PLANT.

Earth	4 feet.
Red shale rock	154 "
Depth	158 "

Water, 25 gallons per minute.

FLEMINGTON, AT H. E. DEATS'.

Clay and gravel	26 feet.
Red shale rock	120 "
Depth	146 "

Water, 40 gallons per minute.

FLEMINGTON, AT TORAN & ABENDROTH'S.

Clay	10 feet.
Red shale rock	119 "
Depth	129 "

Water, 30 gallons per minute.

FLEMINGTON JUNCTION.

Earth	6 feet.
Red shale rock	96 "
Depth	102 "

Water, 15 gallons per minute.

THREE BRIDGES.

Earth and gravel	9 feet.
Red shale rock	27 "
Depth	36 "

Water, 10 gallons a minute.

LAKE VIEW, AT GEORGE EVERITT'S.

Sand and gravel	45	feet.
Red sandstone rock	85	"
Depth	130	"

Water, 6 gallons per minute.

RIDGEWOOD, FOUR MILES ABOVE PATERSON, FOR JAMES WHARTON.

Sand	17	feet.
Red sandstone	66	"
Depth	83	"

Water rises within 30 feet of the surface; yield, 10 gallons a minute.

PASSAIC, AT W. H. ANGLEMAN'S.

Earth	24	feet.
Gravel	40	"
Red sandstone rock	20	"
Depth	84	"

Water, 20 gallons a minute.

PASSAIC, AT HENRY RODEL'S.

Sand and gravel	90	feet.
Red sandstone rock	10	"
Depth	100	"

Water, 25 gallons per minute.

PASSAIC, AT D. J. DOW'S.

Earth and gravel	38	feet.
Red sandstone rock	32	"
Depth	70	"

PASSAIC, AT NORTH BOTANY WORSTED MILLS.

Sand and clay	93	feet.
Red sandstone	7	"
Depth	100	"

PASSAIC, AT PASSAIC BEEF COMPANY'S.

Red sandstone surface, to	171	feet.

Water rises within 17 feet of the surface; yield, 25 gallons a minute.

PASSAIC, FOR RICHARD KIPP.

Coarse sand	51	feet.
Red sandstone	50	"
Depth	101	"

Water rises within 10 feet of the surface; 25 gallons per minute.

PASSAIC, ON BELMONT HILL, NORTHEAST OF THE TOWN.

Three wells, within a radius of one-quarter of a mile.

No. 1:

Earth	10	feet.
Red standstone	65	"
Depth	75	"

No. 2:

Earth	22	feet.
Red sandstone	47	"
Depth	69	"

No. 3:

Earth	18	feet.
Red sandstone	22	"
Depth	40	"

All are good wells for house use.

PASSAIC, AT ELECTRIC LIGHT COMPANY'S PLANT.

Sand and gravel	20	feet.
Red sandstone rock	105	"
Depth	125	"

This well will give, at 25 feet from the surface, 375 gallons of water per minute.

PASSAIC, AT BOTANY WORSTED MILLS.

Fine sand and gravel	100	feet.
Red sandstone rock	100	"
Depth	200	"

Water, 3 gallons per minute.

PASSAIC, AT JOHN GRAY'S.

Earth	12	feet.
Red sandstone rock	43	"
Depth	55	"

Water, 5 gallons per minute.

SOMERSET, TWO MILES SOUTH OF PASSAIC, FOR J. AGRAMONTE.

Earth	11	feet.
Red sandstone	40	"
Depth	51	"

BELMONT, BERGEN COUNTY, AT BOTANY WORSTED MILLS.

Earth and gravel	30	feet.
Red sandstone	51	"
Depth	81	"

ARLINGTON, AT A. W. SCHULER'S.

Sand and gravel	42	feet.
Red sandstone rock	10	"
Depth	52	"

Water, 10 gallons a minute.

ROSELLE, AT J. H. CHILVER'S.

Earth	10	feet.
Red shale rock	107	"
Depth	117	"

Water, 15 gallons a minute.

PLAINFIELD.

Earth and gravel	65	feet.
Red shale rock	35	"
Depth	100	"

Water, 15 gallons a minute.

LEBANON, HUNTERDON COUNTY, FOR A. L. RAMAY.

Earth and clay	53	feet.
Soft, crumbling rock, resembling gray rock	12	"
Depth	65	"

HAMDEN, HUNTERDON COUNTY.

Red shale	51 feet.

FLEMINGTON, AT E. W. BARNES'.

This well is located on a hill one mile west of the town, on the change between the red shale and the blue rock.

Depth	120 feet.

Water, 20 gallons per minute.

FLEMINGTON, AT ELECTRIC LIGHT COMPANY'S PLANT.

Earth	4 feet.
Red shale rock	154 "
Depth	158 "

Water, 25 gallons per minute.

FLEMINGTON, AT H. E. DEATS'.

Clay and gravel	26 feet.
Red shale rock	120 "
Depth	146 "

Water, 40 gallons per minute.

FLEMINGTON, AT TORAN & ABENDROTH'S.

Clay	10 feet.
Red shale rock	119 "
Depth	129 "

Water, 30 gallons per minute.

FLEMINGTON JUNCTION.

Earth	6 feet.
Red shale rock	96 "
Depth	102 "

Water, 15 gallons per minute.

THREE BRIDGES.

Earth and gravel	9 feet.
Red shale rock	27 "
Depth	36 "

Water, 10 gallons a minute.

BORED WELL AT METUCHEN, FOR MISS MARGARET R. ROBBINS.

Depth, 64 feet.

This well is near the Pennsylvania railroad station. Water in red shale at 64 feet. About 25 feet of red drift next the surface in this well.

BORED WELL WEST OF PERTH AMBOY.

Diameter, 4 inches; depth, 84 feet.

This well was sunk for Therklesen and Brown, near Keasby's brick factory, west of Perth Amboy.

	Commenced in bottom of dry well at the depth of	20 feet.
40 feet.	Blue clay	20 to 67 "
5 "	Sand, with water	67 " 72 "
12 "	White clay	72 " 84 "

White sand, with water, under white clay—evidently the same water as reported from Keasby's wells two years ago.

BORED WELL IN THE CITY OF PERTH AMBOY, FOR FARRINGTON AND REMYON, AT THEIR RESIDENCE ON HIGH STREET.

Sand and gravel (drift) to....96 feet.
Then very coarse gravel, with water.

BORED WELL TWO AND ONE-HALF MILES NORTHWEST OF NEW BRUNSWICK, FOR STEPHEN G. WILLIAMS.

Depth, 60 feet.

A well at this place was deepened to the above depth. The country is all red shale. Plenty of water was obtained.

BORED WELL NEAR FORD'S CORNERS, FOR WM. F. CUSTER.

This well is a short distance southeast of a well drilled for Hans Errickson, on ground about eight feet higher, and noted in the report of last year.

HAMDEN, HUNTERDON COUNTY.

Red shale.......... 51 feet.

FLEMINGTON, AT E. W. BARNES'.

This well is located on a hill one mile west of the town, on the change between the red shale and the blue rock.

Depth.......... 120 feet.
Water, 20 gallons per minute.

FLEMINGTON, AT ELECTRIC LIGHT COMPANY'S PLANT.

Earth	4 feet.
Red shale rock	154 "
Depth	158 "

Water, 25 gallons per minute.

FLEMINGTON, AT H. E. DEATS'.

Clay and gravel	26 feet.
Red shale rock	120 "
Depth	146 "

Water, 40 gallons per minute.

FLEMINGTON, AT TORAN & ABENDROTH'S.

[illegible]ay	10 feet.
[illegible] shale rock	119 "
Depth	129 "

[illegible]r, 30 gallons per minute.

FLEMINGTON JUNCTION.

[illegible]	6 feet.
[illegible]ock	96 "
[illegible]	102 "

[illegible]llons per minute.

THREE BRIDGES.

[illegible]	9 feet.
[illegible]	27 "
[illegible]	36 "

[illegible]inute.

Sec. 4.—Bored Wells of which Information has been Obtained from Other Sources.

BORED WELL NEAR METUCHEN.

Elevation, 140 feet; depth, 162½ feet.

A well has been bored on the hill north of Metuchen, not far from the village. It is located at the residence of Charles Corbin, who furnished the record below, which we have received through the kindness of Dr. A. C. Hunt:

Red shale drift	70 feet	= 70 feet.
Quicksand	30 "	= 100 "
Clay	32½ "	= 132½ "
Rock	30 "	= 162½ "

Stratigraphy of the Fish House Black Clay and Associated Gravels.

Fossil Horse, Unionidæ and Plant Remains. The Age of the Beds much Later than that of the Surrounding Cretaceous Plastic Clays of the Region.

RECORDS OF TEST-BORINGS AND OF WELLS PUT DOWN FOR WATER-SUPPLY.

Immediately northeast of Fish House station, on the Camden and Amboy Division of the Pennsylvania Railroad, five miles from Federal street ferries, Camden, and near the Delaware river, there is a very extensive excavation in a bed of black clay, which has been worked for many years for the manufacture of red building-brick, fire-brick and terra-cotta pipe. This deposit has been *called* in former reports the Fish House clay-bed. The locality on the river has been known to boatmen as the " Peashore," and some writers have referred to it under that name. But the name Fish House may be regarded as permanently established, both geographically for the place and geologically for the black clay-bed.

The floor of the excavation is nearly level and has an elevation of eighteen to twenty-five feet above tide. It consists of an iron-stone crust which everywhere marks the base of the black clay and separates it from a medium fine cross-bedded gravel underneath.

In the excavations the clay has shown a maximum thickness of about twenty-five feet, a small part of the upper portion being yellowish in color, while the rest, when freshly dug and before weathering, is quite black, with the exception, occasionally, of about one foot of a yellowish shade at the base next the iron-stone. Near the base of the bed there is a layer containing casts of fresh water mussels, *Unio* and *Anodonta*. A short distance above the shell layer there have been found portions of at least two, and as we shall see beyond, of probably four individuals of an extinct fossil horse, while throughout the bed there occur flattened tree stems nearly changed to lignite, though not so thoroughly so as the plants in the adjacent white and yellow clays of the neighborhood. Over the clays there is a thin layer of coarse gravel, and above this a greater thickness of fine

gravel with, at some places in the latter, an interbedded fine sand. In these surface deposits there were found early the present year, scattered in isolated spots over a few acres in extent, buried upright, coniferous tree stumps with the wood well preserved and in natural condition, without change, that is, neither silicified nor lignitized.

The black clay, the overlying surface deposits, and the life forms in both, will be referred to again more in detail.

The Fish House clay is located within the area occupied by the belt of plastic fire and pottery clays that constitutes the Raritan or basal division of the Cretaceous formation in New Jersey. The facts now in hand, and which will be presented in this paper, demonstrate that the black clay and the gravels above and immediately below it rest unconformably upon the Cretaceous white clays, sands and gravels and are of much more recent age.

The age of the black clay has been variously assigned by different authorities, being regarded by some as Cretaceous and by others as either Pliocene or Pleistocene. We cite below these authorities and their opinions.

Previous to 1868, according to Prof. E. D. Cope, Prof. [W. B.] Rogers and others who had examined the bed regarded it as Cretaceous.†

In 1868 Dr. Lea considered the bed Cretaceous.*

Almost simultaneously the same year (1868) Prof. E. D. Cope believed it to be Pliocene, and remarked that "the underlying coarse red sand is, in all apparent respects, identical with the material of a stratum which underlies the soil" near Haddonfield, and which he says "rests unconformably upon the Ripley division of the Cretaceous," and "may be the same bed." † As will be noted later, the last named authority now regards it as belonging to a still later period, the Pleistocene. See page 208.

In the Geology of New Jersey, 1868, page 256, and again, page 339, the then State Geologist, Prof. Geo. H. Cook, includes it within the Cretaceous. It is known, however, that shortly afterwards he changed his view as to its age, and in the annual report of the State Geologist for 1878, issued by him, it is stated, page 67, "that the bed is more recent than the plastic clay formation;" also, page 68, that it "may lie upon and abut against" these older fire-clays; that is, it is more recent than the Cretaceous, to which division the plastic fire-clays belong.

*Proc. Acad. Nat. Sci., Phila., 1868, p. 162.

†Trans. Amer. Philos. Soc. Vol. XIV, N. Ser., pp. 249, 250 The Fresh-water Clays of the Pea Shore.

It is known to the writer that the present State Geologist, Prof. J. C. Smock, also early regarded the bed as more recent than the Cretaceous, and though he has not thus appeared in print over his own signature, it may be authoritatively stated that the reference last noted from the report for 1878 was originally prepared by him as assistant geologist, and was based upon an examination personally made in the field.

In 1883 Dr. C. A. White says that these clays "are almost certainly of post-Tertiary date."*

In 1884 Prof. R. P. Whitfield referred the beds to the Cretaceous,† evidently following Dr. Lea, and, we apprehend, misunderstanding Prof. Cope, who, he states, "appeared to consider them" (the contained *Unionidæ*) "as occurring in beds actually below the lowest of the green marls," which is diametrically the opposite of any correct inference to be drawn from either the Pliocene age to which formerly, or the Pleistocene age to which latterly, Prof. Cope, as above noted, has really referred the beds.

In 1884, Prof. H. Carville Lewis, in a field lecture given on the spot, at which the writer was present, stated that the bed was interglacial. See page 211.

This lecture he afterwards prepared for publication in the columns of the Philadelphia *Public Ledger*. Slips were cut from the papers containing this lecture and others in the same course, and were arranged by him on note sheets, forming a small pamphlet, which is now bound, with other geological papers, and may be consulted in the Academy's library.‡

In 1889 § Dr. P. R. Uhler refers the Fish House black clay to a series of beds which he states are *above* the Potomac (Raritan) and below the Marl series for which in 1888 || he had proposed the name of Albirupian, thus practically placing the clays in the Cretaceous. He claims also that the Flora and Fauna characterizing the Albirupian are of a younger type than occurs in the Potomac, and instances among the faunal forms "shells apparently related to Unio."

In 1894, Prof. R. D. Salisbury established and partially mapped the Pensauken formation—a bed of fine and coarse gravels which is

*A Review of the Non-Marine Fossil Mollusca of North America, 1883.

† Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, Vol. I, pp. 243 to 252.

‡Geol. Tracts, Library of Acad. Nat. Sci., Philada, Vol. 43a, Part XI, page 13.

§ Trans. Maryland Acad. Sci., 1892, p. 185 to 201.

|| Albirupian Formation, &c. Proceedings Amer. Philos. Soc., 1888, pp. 42-53.

widely spread over southern New Jersey, and which he shows overlies unconformably the Cretaceous, Eocene and Miocene deposits, and states that the Fish House clays are post-Pensauken.* In 1895, however, after further study of the Pensauken, he modified this view slightly so as to include these clays *within* the Pensauken, with the proviso, "if present interpretations are correct."†

Late the present year (1896) Prof. H. A. Pilsbry read a paper before the Academy of Natural Sciences of Philadelphia,‡ in which he considers the bed a lagoon-like fluviatile deposit on the margin of the ancient Delaware river, and refers it to the Pleistocene period, with the further remark that "it is either interglacial or preglacial, probably the latter." We shall refer beyond, at considerable length, to Prof. Pilsbry's paper.

The present writer, since his first acquaintance with the bed, in the year 1884, has regarded the occurrence therein of an extinct horse, which had previously been reported by Prof. Cope, § as alone and of itself sufficient evidence in favor of a very recent geological age for the bed, and this view was only the more firmly established when, in the year 1888, he himself also obtained some teeth and portions of the enclosing and other adjacent bones of another individual horse. It also seemed to him that the views of those who regarded the bed as Cretaceous must have been formed from a misinterpretation of the facts upon which such views were based. It is therefore the object of this paper to prove that these facts, properly understood, cumulatively harmonize with the evidence presented by the Equus remains in favor of a much more recent geological age than the Cretaceous.

In short, the writer would place it within the Pensauken, leaving the determination of the exact equivalency of that bed in the geological column to Prof. Salisbury, who, under the auspices of the State Survey, is still working upon the formation.

We will now review the evidence presented by the Unionidæ, or fresh-water mussels, after which we will consider that presented by the horse, or the genus Equus. Some notice will then be made of the plant stems found in the clay. This will be followed by the presentation of some purely stratigraphical evidence which has been

* An. Rep. State Geol. of N. J., 1894, page 108.

† An. Rep. State Geol. of N. J., 1895, page 8.

‡ Proc. Acad. Nat. Sci. Phila., 1896, pp. 567 to 570.

§ Trans. Amer. Philos. Soc., Vol. XIV., N. Ser., pp. 249, 250.

learned from the examination and study of numerous borings that have been made the past year, and which extend in two directions, at right angles to each other, entirely across the field occupied by the Fish House clay, and in one of these directions beyond it.

FRESH-WATER MUSSELS, UNIO AND ANODONTA, IN THE FISH HOUSE CLAY.

These fresh-water mollusks are found in a layer near the base of the bed. They were probably first brought to notice by Prof. E. D. Cope, who collected and handed some forty individual specimens to the late Dr. Isaac Lea. Dr. Lea identified and described therefrom ten of the twelve species now known from this locality in a paper published in the proceedings of the Academy of Natural Sciences of Philadelphia for the year 1868. Dr. Lea evidently, as his paper shows, adopted the view that the bed was Cretaceous because of its geographical position within the area occupied by beds of that age. Descriptions and figures of the entire twelve species, the other two of which were established by Prof. R. P. Whitfield, have been published at the close of the first volume of Whitfield's Paleontology of the Cretaceous and Tertiary of New Jersey.*

Prof. Whitfield also, as the first paragraph of his paper indicates, evidently partly on the authority of others, and partly as noted above from a misconception of Prof. Cope's views,† regarded the fossils as Cretaceous, though he states that with respect to their geological position *he* offers no opinion, not having visited the beds himself. This reference to the Cretaceous we think erroneous for reasons we proceed to note.

Prof. H. A. Pilsbry, in the paper before referred to, page 204, and which was published in the proceedings of the Academy of Natural Sciences of Philadelphia for 1896, under the title of "Geology of the Mussel-bearing Clays of Fish House, New Jersey," calls attention to the very close affinity of these mollusks to those now living, and notices the fact that Dr. Lea had evidently observed the same when he assigned to the fossils a specific nomenclature derived from the same root-words that had previously been used in naming the living forms. In illustration we give below in parallel columns the specific nomenclature of the fossil and existing forms. To the latter we append their habitats as kindly furnished us by Prof. Pilsbry :

* Brachiopoda and Lamellibranchiata of the Raritan Clays and Green Sand Marls of New Jersey, pp. 243–252.

† Consult Prof. Cope, Trans. Amer. Philos. Soc., XIV N. Ser., pp. 249 and 250.

Fossil at Fish House.	*Allied Living Forms.*
	Habitat East of the Alleghanies.
Unio nasutoides, Lea	Unio nasutus, Say. Hudson, Delaware and Chesapeake drainages.
Unio cariosoides, Lea.	Unio cariosus, Say. Delaware, Chesapeake and Potomac drainages.
Unio humerosoides, Lea	Unio humerosus, Lea. Rivers of North Carolina.
Unio roanokoides, Lea	Unio roanokensis, Lea. Rivers of North Carolina, and U. northamptonensis, Lea. Connecticut to New Jersey.
Unio radiatoides, Lea	Unio radiatus, Lamarck. Great Lakes and N. E. Atlantic States.
	Habitat Exclusively West of the Alleghanies.
Unio subrotundoides, Lea	Unio subrotundus, Lea. Northern Mississippi drainage.
Unio ligamentoides, Lea	Unio ligamentinus, Lamarck. Great Lakes and Northern Mississippi drainages.
Unio alatoides, Lea	Unio alatus, Say. Great Lakes and Northern Mississippi drainages.
Anodonta grandioides, Lea	Anodonta grandis, Say. Great Lakes and Northern Mississippi drainages.
Anodonta corpulentoides, Lea	Anodonta corpulenta, Cooper. Great Lakes and Northern Mississippi drainages.

Similarly Prof. Whitfield continues the parallelism:

Unio rectoides, Whitfield	Unio rectus, Lamarck. Great Lakes and Northern Mississippi drainages.
Unio praeanodontoides, Whitfield	Unio anodontoides, Lea. Mississippi and Gulf drainage.

The term Northern Mississippi drainage as used above comprises that stream and its tributaries north of the mouth of the Ohio, including the latter river and the Missouri and their lateral streams.

Both Dr. Lea and Prof. Pilsbry note that a considerable number of the species have no affinity to forms now living in the drainage of the Atlantic coast. Dr. Lea notes the living counterparts of these as occurring in the Ohio and other western waters, and Prof. Pilsbry, as already stated, as inhabiting the Great Lakes and St. Lawrence, and the Upper Mississippi drainage. The latter also states, however, that certain forms, characteristic especially of the Lower Mississippi and its tributaries, but occurring also in the Upper Mississippi and some of its tributaries, are entirely wanting in the Fish House fauna, which he says is "therefore to be assimilated rather with the Great Lake system than with the Mississippi and Ohio drainage," and adds that "the species prob-

ably found their way into the Atlantic system in New York State where the Lake and Atlantic waters are in close proximity. They may then have become extinct on the Atlantic slope during the glacial period when the rivers north of Delaware bay were so profoundly affected."

The close resemblance of the fossil to the living forms can be seen by comparison of Lea's Fish House types in the Paleontological collection of the Academy of Natural Sciences of Philadelphia with numerous specimens of existing forms in the Academy's Conchological collection.

Of the forms above listed, Prof. Pilsbury especially states that *Unio ligamentoides*, *alatoides*, *prœanodontoides* and *Anodonta grandioides* and *corpulentoides* have "no modern representatives in the Atlantic drainage south of the Great Lakes and the St. Lawrence river system."

The most numerous of the fossil forms are the two species of Anodonta. Of thirty-four specimens recently collected there by the writer and comprising eight species, ten individuals belong to the two species of Anodonta.

Prof. Pilsbry also on another occasion collected about three dozen specimens, the preponderance of the two Anadonta being in about the same proportion.

While therefore the above list shows that the species whose allied living forms have their habitat in waters exclusively west of the Alleghanies are but slightly greater in number than those whose representatives are now found in the Atlantic coastal waters, the preponderance in the number of individual Unionidæ is much more greatly in favor of the western fauna.

The close resemblance of this fresh-water fauna to that now living, and its occurrence in beds, as noted beyond, which recent test borings show to overlie unconformably the basal beds of the New Jersey Cretaceous, and above all the association therewith of the remains of an extinct horse, *Equus complicatus*, Leidy, to be next noted, cumulatively point to a quite recent age for this bed, and one much later than the Cretaceous.*

*In this connection it may be interesting to note the fresh-water shells now living in the Delaware river at the same locality. Recently there were collected by Prof. Pilsbry, in the quiet waters of the bay or cove formed between the shore at Fish House and the Fishers' Point dyke, the following:

Unio nasutus, Say	Unionidæ (bivalves).
Unio complanatu , Solander	
Anodonta fluviatilis, Dillwyn	
Alasmondonta undulata, Say	
Goniobasis Virginica, Say	Gastropoda (univalve).
Campeloma decisum, Say	

It may be observed that only one of these, U. nasutus, occurs in the fossil bed, and this one is quite extended both in geological and geographical distribution in the Eastern United States.

FOSSIL HORSE IN FISH HOUSE CLAY.
EQUUS COMPLICATUS—LEIDY.

In the transactions already referred to of the American Philosophical Society for the years 1868 and 1869, new series, Vol. XIV, page 250, Prof. E. D. Cope accurately illustrates with a figure the stratigraphy of the Fish House clay beds, and correctly shows the position of the Unionidæ near the base of the black clay. In the text and in the figure he notes the association therewith of the remains of a fossil horse, which he at that time referred to *Equus fraternus*, Leidy. In the Geology of New Jersey, 1868, page 741, Prof. Cope further states that this specimen was found twenty feet below the surface. In the year 1888 the writer obtained from a workman in the clay-pits some of the teeth and portions of the maxillary bone of a fossil horse, which Prof. Cope has kindly identified as *Equus complicatus*, Leidy, which he says belongs to Pleistocene time. It may possibly be the same in species as the specimen formerly noted by Prof. Cope, but which is not now accessible for comparison, the difference in nomenclature being probably due to some revision thereof, the result of the advance made in recent years in the comparison and critical study of the fossil remains of this genus.

The spot in the bank which the workman pointed out to the writer as that whence the remains were obtained was about twelve feet below the top of the clay, from which had already been removed, by stripping, a covering of some six feet of surface gravels. The teeth and bones are black in color, both within and without, and there is therefore no reason to believe otherwise than that the remains were actually found in undisturbed strata at about the depth named. The specimen is now in the collection of the Academy of Natural Sciences, of Philadelphia. A photo reproduction is presented on plate X.

The specimen consists of a portion of the right cheek and upper maxillary bone, with the first and second milk premolars and the first and second true molars in place in their respective processes. The third milk premolar was missing when the writer obtained the specimens, though its process intervenes between the second milk premolar and the first true molar. This process is apparently occupied by the succeeding premolar, which had not yet come into view. There were also fragments of bone from the upper left side containing the first and second true molars.

A

Cross Section, First Molar (A) above.

Fossil Horse (Colt), Equus Complicatus, Leidy. From Black Clay. Fish House, N. J.

The first true molar on either side each shows very slight evidence of wearing of their crowns, while neither of the second true molars present any such evidence and had probably not protruded through the gum—in fact they had but barely risen above the maxillary bone. This dentition indicates a colt about two years of age.

Professor Cope informs the writer by letter that the horse remains obtained by him are those of an adult, and "consist of some superior molars and incisors in the jaw."

The wearing of the crowns of the true molars in the specimen obtained by the writer being so slight, it became necessary, in order to distinguish the intricate foldings of the enamel that are usually seen thereon, to cut across or bisect one of the molars below the crown. For this purpose a lapidary was employed, who so bisected the first true molar on the upper left side about one inch below the top. The drawing on the lower left-hand corner of plate X shows the enamel folds of this transverse section so made, as also the dentine and cementum of the tooth.

Besides this Fish House deposit there is, perhaps, but one other *fossil* deposit of similar or nearly equivalent age known in the region near Philadelphia, and that occurs at Port Kennedy, in the Schuylkill Valley above Norristown, in a fissure in Silurian limestone, filled by deposition in a more recent age. Here well-preserved teeth of the same species of horse have been found in association with two extinct species of giant sloth, the teeth of the mastodon and the remains of numerous other animals.

The association of fossils indicates, according to Prof. Cope in a paper in the Proceedings of the Academy of Natural Science for 1895, that the age of the deposit in the fissure is Pleistocene.

Closely related horse-remains, *Equus intermedius, Cope,* and three species of sloths from Petit Anse Louisiana have been named, figured and described by Prof. Cope in the Proceedings of the American Philosophical Society, Vol. XXXIV, pages 458 to 468. These also indicate, as stated by Prof. Cope in a personal interview, a Pleistocene fauna, the equivalent, or nearly so, of the Equus beds of Texas, and which are related by the similarity of their contained fossil life forms to certain strata in Oregon, where the designation Equus beds was first applied.

The crowns of the milk premolars in the writer's Fish House specimen somewhat resemble in the convolutions of the enamel those

of Prof. Cope's figure of *Equus intermedius* from Louisiana in the work above cited. These are, however, much more complicated in the cross-section of the first *true* molar, from an examination of which, as above stated, the specific name of *Equus complicatus*, Leidy, has been assigned.

We have compared the dentition of this Fish House colt with that of a number of museum specimens of the horse of to-day, and with the following results: The teeth are much more robust than those of the adult race-horse, Edwin Forrest, whose skeleton is mounted in the Museum of the Academy of Natural Sciences of Philadelphia. The two diameters also measure one-eighth to three-sixteenths of an inch greater than the teeth of the largest horse crania in the Academy's collections. They, however, measure almost precisely the same as the teeth of two specimens of the large English draft-horse that are in the Museum of the Wagner Free Institute of Science. If the bony skeleton of the Fish House specimen was like that of the present horse, then this colt represents an animal which, in the adult state, was as large or larger than the largest of existing horses. Without, however, any other of the bones, as of the limbs, &c., we cannot be positive as to its size, and the animal may have been one with a large head and relatively small body, such as the zebra and quagga of to-day.

Besides the two individuals of the fossil horse already noted, there are in the collections of the Academy of Natural Sciences of Philadelphia one bone, a Patella, and a fragment of another, possibly from one of the long bones of a limb, that probably represent two additional individuals. The Patella is about one-fifth less in size than the Patella of the Wagner Institute mounted skeleton of the large English Draft Horse. It was personally obtained in the year 1892 directly from the black clay by J. E. Ives, at that time a student at the Academy. This fact was recently furnished at a personal interview with J. E. Ives. The specimen was presented to the Academy and is noted in the list of presentations published in the Proceedings, 1892, page 514, though rather vaguely stated to be from Camden. The fragment which was probably from the end of one of the long bones of a limb of probably another individual horse was procured by the writer the same year, 1892, from a workman who had carried it to home some months previously.

VERTEBRATE AND INVERTEBRATE FOSSILS AND ALSO PLANT REMAINS AT FISH HOUSE AS NOTED BY PROF. H. CARVILL LEWIS.

Before leaving the subject of animal remains found in the Fish House clays and before introducing our own remarks upon tree and plant stems therefrom, we will quote verbatim Prof. Carvill Lewis upon the contained fossils, both animal and vegetable.* He says: "At Fish House, a few miles above Camden, there occurs a stiff dark clay of interglacial age which is of interest in that it is the only one of the Delaware river clays of Quaternary age that contains fossils. Eight species of the large mussel shells (Unios and Anodontas), the skull of an extinct horse, bones of the wolf, scales of fishes, bark of pine and birch, leaves of oak, maple and other trees are among those which have been found here. Some of the Unios are identical with those now living in the Ohio river."

Were the author of the above, the present writer's late friend and preceptor, now living, it would be desirable to learn from him more definitely regarding these fossils, and especially the plants.

We have, however, recently been reliably informed that for the purpose of study Prof. Lewis had collected together at one time in some trays at the Academy of Natural Sciences, of Philadelphia, specimens of Unionidæ, including, besides those already belonging to the Academy's collection, a number obtained by himself; also, the skull of a horse,† and some bones not those of a horse, and that he and Prof. Cope held a consultation about the same, the bones other than those of the horse being pronounced by Prof. Cope to be those of a wolf. Corroborative of the fish scales we have been informed by a resident of Delair that in connection with the finding of "clams" (Unionidæ) near the bottom of the black clay in digging a well on premises occupied by him some years since, he had obtained the impression of a fish, and that he had given away the specimen to a geologist who had called on him shortly afterward.

* Field Lectures in Geology in the vicinity of Philadelphia, by H. Carvill Lewis, 1884. (From the Public Ledger April-June, 1884). Geol. Tracts Acad. of Nat. Sci., Philada., Vol. 43a, part XI, page 13.
The title given above is in MSS. in the handwriting of Prof. H. Carvill Lewis. The text is in print on slips cut from the Philadelphia "Public Ledger."

† This was probably the specimen before referred to as having been obtained by Prof. Cope.

FLATTENED TREE AND PLANT STEMS IN FISH HOUSE CLAYS.

Besides the molluscan and vertebrate fossils before noted there also occur in the Fish House clay a considerable number of larger and smaller fragments of flattened plant stems or tree-trunks. This flattening is probably the result of gradual pressure for a long period of time, and is very noticeable. One specimen measured was ⅝ of an inch in the shorter diameter and 2¾ inches in the larger diameter. In another the two diameters were respectively 3 and 8 inches.

Unlike the fossil trees, to be later described, from an overlying and still more recent bed these trees do not appear, on microscopic examination of preparations of sections, to be coniferous.

Since writing the above paragraph, the writer has obtained from this bed considerable sized masses of vegetation in the form of peat. The vegetable fibers were flattened and closely massed together in laminæ and consisted of the stems of plants and probably also of the roots. From one of the largest stems he prepared thin semi-transparent, transverse, radial, and tangential sections for examination under the microscope. This specimen proved coniferous, and while much pressed and distorted, several undoubted tracheids or bordered pits were clearly seen. Other specimens of the same non-coniferous wood noted before were also procured on this occasion.

The character of the plants further than as above noted the writer leaves for the future determination of some competent paleobotanist When so determined it will probably not conflict with the evidence as to age already presented by the molluscan and vertebrate remains.

Before leaving the consideration of the contained plant remains we will notice the occurrence of a single leaf from the locality, but whether from the black or white clays is not certainly known.

NOTE ON TILLÆPHYLLUM DUBIUM, NEWBERRY—A FOSSIL LEAF FOUND AT FISH HOUSE.

Prof. J. S. Newberry, in a Monograph on the Flora of the Amboy Clays* has described and figured from Fish House a fossil leaf to which he assigned a new generic and specific name, *Tillæphyllum dubium*, but it seems to the writer, rather significally remarks that "it resembles some leaves of our basswood, such as could be collected in almost any forest."

*Monograph U. S. Geol. Survey, Vol. xxvi, page 109, Plate xv, fig. 5.

striking unconformity between the two deposits. We are informed by Augustus Reeve & Son that a somewhat triangular tongue of white and dove-colored clay has been dug away, which formerly extended from this base on the River road toward the point of junction on the west of the two cartways.

On the map we have outlined the area formerly occupied by this tongue of white clay by a dotted semi oval line with the letters W. C. within.

This clay is stated to have had a maximum thickness of about twenty feet, but to have declined upon its western margin to a thin sheet. The black clay which had occupied all the rest of the excavation surrounding this tongue overlaid the thinner western margin of the plastic clay, but did not extend over it to the eastward where it was thickest, near the River road, where, as already stated, the superficial gravels can be seen to rest directly upon the plastic clay, as they can likewise be seen to rest upon the black clay to the north and to the south. These relations of the gravels and the black clays are now well shown in Hatch's side of the bank on the north side and in Reeve's bank on the south excavation.

There is thus demonstrated a considerable unconformity between the black and the white clay deposits, and that the black were laid down over the white and are therefore the more recent. Other evidences of this unconformity we now proceed to note:

(1.) Within the past few years quite a number of wells have been bored at Delair for water-supply. Some of these, which were in the area occupied by the black clay, have passed through it and through undoubted *white* plastic clays somewhat further down, before reaching a water-bearing sand or gravel.

(2.) During the present year a large number of test-borings have been made to ascertain the thickness and extent of the Fish House clay bed in order to fix the compensation to be paid by the Pennsylvania Railroad Company for the right-of-way of its new seashore route.

(3.) Other test borings have also been made for the railroad company on both banks of the river, and also beneath its bed, preparatory to the building of the railroad bridge and its approaches. The exact locations of these various borings, numbered 6, 6a, &c., to 52, are shown on the accompanying map, plate XI, which has been prepared by a careful draftsman from official surveys of the Pennsylvania Rail-

road Company and of the Delair Land Company. P. D. Staats has also made a topographical survey, and placed thereon, while in the field, contours for each five feet of elevation.

The topography of the present excavations in the black clay northeast of Fish House and of two excavations in the white clay southeast of the same, was also carefully surveyed, and is outlined on the map; the contours show the depressions of their floors.

The area from which black clay has been taken is marked B. C., and those from which white clay has been removed are marked W. C.

Detailed records of these 52 borings are appended at the close of this paper. (Pages 218, to 244.) Only one of these, No. 9, has been previously noted in the annual reports. *

The wells bored at Delair for water-supply, after penetrating surface-beds of greater or less thickness, have passed through several feet of unmistakable white plastic clay before reaching the water-bearing gravels. In some of these wells the surface-deposits below the first few feet consisted of black clay and an underlying gravel; while some which were toward the river and were beyond the western margin of the black clay did not find it, they, however, penetrated the same gravel which in the others underlaid the black clay.

One of these wells on Derousse avenue, midway between the C. and A. railroad and the River road, was dug to the base of the black clay, finding near the bottom, at the depth of about twenty-two feet, what were described as "clams" and which undoubtedly were fresh-water mussels, such as have already been noted as occurring in the bed near Fish House station. Below this first horizon this well was continued by boring, first penetrating the underlying yellow gravel, and then, at 55 to 73 feet, about 18 feet of strata, described as stiff, white fine clay and white sandy clay, before reaching the desired water-bearing gravel. This white clay stratum and the water-bearing gravel beneath it, are certainly Cretaceous.

Through the courtesy of J. F. Stuart and others, civil engineers for the railroad company, and also of Hatch Brothers and of Augustus Reeve & Son, owners of the Fish House black clay banks, and also through the kindness of W. H. Knowles, contractor for artesian borings, we have been placed in possession of considerable information respecting these various test borings east of the Camden and Amboy Railroad, and have been permitted to examine several full series of specimens of the same.

* Annual Rep. State Geol., 1895, pp. 69-70.

We have also been furnished with blue-prints of carefully constructed vertical sections, one of which is a west and east section across the beds from near the River road to near the Burlington pike, while another is a north and south section from near Derousse avenue, Delair, to the Cove road at Fish House station, passing directly across the excavation made in Hatch's and in Reeve's banks, but running approximately parallel with the strike of the beds. There were also three short cross-sections of Reeve's bank at the southern end of the area.

All of the test borings made through the Fish House clay-bed passed into a yellowish gravel within which most of them terminated. Three borings, Nos. 33, 34 and 37, however, either on or near the Cove road, on the southern margin of the Reeve property, passed from this underlying gravel into white clays unmistakably Cretaceous.

One boring, No. 14, on the west and east section first noted, and which was put down beyond the eastern margin of the black clay to a greater depth with reference to sea level than the other borings on that line except one, No. 18, also encountered unmistakable white plastic clay beneath a yellow gravel apparently the same as that which underlies the black clay.

The one boring, No. 18, above excepted was on the lowest ground along the section line and near its eastern end towards the Burlington pike. Though not so deep as some of the other borings on the line, its bottom was about ten feet nearer sea level. Indications of white plastic clay were found at its base.

The test borings, Nos. 0 to 6 and 6a, put down preparatory to the building of the bridge and approaches and along the line of the same all entered Cretaceous strata beneath a greater or less thickness of superficial beds. A careful examination of the specimens from the three sets of borings above described and of the records as appended to this paper show that at varying depths below tide-level the uneven floor of the Cretaceous plastic clays is met with and that upon this uneven floor is deposited fine yellow gravel such as can be seen beneath the iron stone crust forming the floor of the black clay excavation, and above this the black clays and associated orange-yellow clays.

For further information respecting these borings read, Notes on Test Borings Nos. 0, 1, 2, 3, 4 and 6, page 219; and, Special notes on Test Borings Nos.10 to 42, pages 227 and 228.

SUMMARY OF THE FISH HOUSE BEDS.

Under the name of the Fish House beds we would include the black clay and the associated orange-yellow clays that generally form its upper portion, and also a similar orange-yellow clay that sometimes occurs beneath it, together with an underlying laminated and cross-bedded stratum of coarse yellow sands and medium coarse yellow gravels. As to the age of these beds we incline to the view already published in former annual reports, by Prof. R. D. Salisbury, that they are Pensauken, for the reason that on the Reeve property, at the southern side of the Fish House excavation, where the underlying gravel consists of larger pebbles than at the northern end, on the Hatch property, and where, consequently, its character can be better studied, occur pebbles the size of shellbarks and larger, some of which are of partially decomposed sandstones and shales, apparently Triassic, which can be readily crumbled between the fingers. Such pebbles are characteristic of that formation. If this nomenclature be correct, we have additional proof of the unconformity of the Fish House beds with the Cretaceous, and also of their much later and in fact their almost recent date, since Prof. Salisbury, in the last three annual reports of the Survey, has traced the Pensauken as a widespread formation, to the eastward overlapping successively the beveled or upturned edges of the plastic clay, clay marls, and the three true marl divisions of the Cretaceous, and also those of the Eocene and Miocene formations.

In short, since the white clays were deposited and before the black clays were laid down in the region of Delair and Fish House, nearly the entire coastal plain portion of New Jersey, and, in fact, nearly the whole Atlantic coastal plain southward to Florida, has been built up. This length of time covered nearly all of *four geological periods*, viz., the Cretaceous, Eocene and Miocene, and much of the succeeding time during which the superficial gravels, known as the Pensauken, were laid down so as to cover the slightly upturned edges of the three preceding periods just named.

In harmony with this view of the recent age of the deposit, and, indeed, conclusive proof thereof, is the occurrence, as above recorded, of two well-authenticated specimens of portions of the crania and dentition of an extinct fossil horse obtained several years apart by Prof. E. D. Cope and by the writer, the circumstances of the finding

each of which was carefully investigated and established by each of us at the respective times when each specimen was secured.

The occurrence of such fossil horse is further emphasized by the existence of in each case a single skeletal portion from each of probably two other individuals obtained later than either of the above, but at different times, by J. E. Ives and the writer, under circumstances which may be regarded as also fully authentic.

Not inconsistent with the late age thus indicated is the occurrence of the Unionidæ or fresh-water mussels, so long by some considered to be Cretaceous, but whose affinities may now be regarded as quite as fully indicative, if not more so, of a more recent age, and although it may be said that Cretaceous Unios from the West differ generally but slightly from recent forms, yet coupled with the occurrence of the fossil horse, which in anything at all resembling the size and species of the specimens found did not extend below the Pliocene, if, indeed, it went that far down, we feel we are compelled to regard the Fish House naiad fauna as quite recent geologically. It may be further said that no fossil horse, no matter how primitive, has been found so far back in time as the Cretaceous.

The evidence presented by the plant-remains, so far as they have been studied, is quite meager, but it is probable that should their affinities be well made out they too would fall into harmony with our conclusions.

Appendix to the Statigraphy of the Fish House Black Clay and Associated Gravels.

TEST BORINGS AND WATER SUPPLY-WELLS AT POINT NO POINT, PA., IN THE BED OF THE DELAWARE RIVER, AND AT DELAIR AND FISH HOUSE, N. J.

The following borings, numbered Nos. 0, 1, 2, &c., to 52, might have been included under the sub-heading, Wells in the Southern Part of the Cretaceous Belt, in a previous portion of this report. They do not, however, all of them enter the Cretaceous, quite a number of them being only in the superficial strata overlying the beds of that age. A large number of them also were not bored for water-supply, but as test borings for reasons which will appear later. They form a group

by themselves that are opportune at this time to demonstrate the geological relation of certain yellow and black brick clays and white and dove-colored plastic clays that have long been worked at Fish House, N. J., for economical purposes and about which authorities have differed for many years as to the geological age of each. For this reason their records are placed here in immediate connection with the preceding papers on the Stratigraphy of the Fish House Black Clay, &c.

Borings Nos. 0 to 5 were made on the Pennsylvania shore and in the bed of the Delaware river. The remainder were put down in New Jersey. The latter may be found located on the accompanying contour map, plate XI, which has been prepared from accurate official surveys. The elevation contours were especially surveyed for this map and placed thereon while on the field by P. D. Staats.

NOTES ON TEST BORINGS NOS. 0, 1, 2, 3, 4, 5 AND 6 ON THE SHORES AND IN THE BED OF THE DELAWARE RIVER AT THE PENNSYLVANIA AND NEW JERSEY RAILROAD BRIDGE BETWEEN PHILADELPHIA, PA., AND DELAIR, N. J.

All of these enter Cretaceous strata.

Early in 1895 a series of six test borings were made by Geo. H. Orcutt on either shore of the Delaware river, and also on the river-bed between Point no Point, below Bridesburg, Philadelphia, on the Pennsylvania side; and Fisher's Point, adjacent to Delair, north of Camden, on the New Jersey side. These borings were preliminary to the building of the abutments and piers for the railroad bridge connecting the Pennsylvania Company's main line at Frankford, Pa., with its Atlantic City route at Haddonfield, N. J.

Through the courtesy of the railroad company's officials the writer was permitted to examine the specimens of the various borings, which had been carefully marked and preserved. The subjoined records have been made from this examination. They follow each other from west to east, and are directly across the strike of the strata. With the records there is included a boring (No. 6*a*) made on the New Jersey bank for water-supply.

We commence the records, however, with a boring (No. 0), made later, or in the year 1896, one block west of Pennsylvania abutment, by another contractor. We have numbered the borings 0, 1, 2, &c., from west to east.

The borings, Nos. 1 and 6, on either shore were made to rock. On the Pennsylvania side soft rock was found at the depth of 87 feet and solid rock at 112 feet. On the New Jersey side, soft rock was reached at the depth of 142 feet and hard rock at 159 feet. Closely corroborative of the latter depth is the information received that some years previously, at the time of the construction of the Fisher's Point dyke, a test boring was made at the landward end of the dyke which reached hard rock at the depth of 168 feet. The foundations for piers Nos. 2, 3, 4 and 5 were made at the depth of about 66 feet. They rest upon coarse sand and gravel strata near the base of the Cretaceous.

No. 0.—Test Boring on the Sea Shore R. R., Carbon Street, Philadelphia.

(Elevation, mean tide level; diameter, 6 inches; depth, 56 feet.

This boring was made on the line of Pennsylvania Railroad Company's new Sea Shore railroad near its crossing over Carbon street, on which is located the Belt Line railroad. This street is one block west of Delaware avenue. The boring was made by the drill and sand-bucket process, by which good specimens of the materials penetrated can be obtained, and the record is therefore of especial value. Samples were taken at every foot. These have been divided with the writer, through the courtesy of the company's engineers. From a careful examination of these we make the following record :

Mud (alluvium), contains *Diatoms*	19 feet	= 19 feet.	Recent.	
Heavy gray gravel	4 "	= 23 "	Trenton gravel. (?)	
Heavy yellow gravel, mixed with fine	5 "	= 28 "	18 feet. Age (?)	
Heavier yellow gravel, with large pebbles	13 "	= 41 "		
White clay	2 "	= 43 "	= 15 feet.	Plastic Clays. Cretaceous.
Yellow clay	2 "	= 45 "		
Orange yellow clay	4 "	= 49 "		
Greenish sandy clay	7 "	= 56 "		

The alluvium at the top contains a mixture of fresh and salt-water diatoms, the fresh-water forms preponderating. This deposit is, of course, quite recent and has the same thickness as has been noticed by the writer in similar deposits in borings elsewhere along the margin of the Delaware river, say about twenty feet. This is its thickness at Cramer Hill ferry, and Gloucester, N. J., and also at the Philadelphia navy yard, on League Island, at the mouth of the Schuylkill. The Gloucester locality is on the margin of the marshes of Newton creek, and the Cramer Hill locality on the former site of a small stream whose channel has been recently diverted by artificial means to the southward.

No. 1.—Test Boring at Point no Point, for Bridge Abutment, Pennsylvania Shore.

Diameter, 6 inches; depth, 112 feet.

Notes on the Diatom, Tricerateum favus, Ehr.

This boring was made on the meadows just inside the dyke that faces the river on the Pennsylvania shore. The following record was made from an inspection of a full series of the borings, which were carefully preserved in the railroad company's office, at Broad street station, Philadelphia.

Meadow mud, contains *diatoms*			3	feet.	Latest Pleistocene.
Loamy clay	3	to	7	"	
Clay, sand and fine gravel	7	"	9	"	
Mud, contains *diatoms*	9	"	12	"	
Sand and gravel	12	"	22	"	
Clay	22	"	25	"	
Sand	25	"	51	"	
White clay	51	"	54	"	Cretaceous.
Sand	54	"	61	"	
Fine gravel	61	"	77	"	
Very coarse gravel	77	"	87	"	
Loose or disintegrated rock, micaceous	87	"	110	"	
Solid rock, micaceous	110	"	112	"	

It is interesting to note that the interval of 9 to 12 feet shows a river mud overlain by fine gravel and sand and loamy clay, and that over the latter is spread the more recent river deposit that now forms the broad stretch of meadow-land seen on the western approach to the bridge. It is further interesting to note that these two muddy

strata contain *diatoms*, mainly fresh-water species, though there are a few forms which thrive in either salt, brackish or fresh waters. Among those so occurring in both these beds is *Triceratium favus*, Ehrenberg, which the writer has seen in Delaware river marsh deposits at various points along the shore from the bay upward to the latitude of Philadelphia. It also occurs fossil in the clays beneath the older portion of the latter city which, a couple of generations back, were used for brick-making, and which may now be found below the surface within the area bounded by the 25 and the 40-foot elevation contours. Diatoms do not occur in Philadelphia clays having a greater elevation than 40 feet.

This diatom is also found in clays not far beneath the surface along a narrow strip of comparatively level land bordering the ocean shore of the State whose elevation does not exceed 40 feet. It should, perhaps, be mentioned that a preparation of cleaned diatoms made from recent river mud at Burlington has failed to yield this specific form.

The record for Pier No. 2 which follows next shows black mud deposits at the depth of 28 to 30 feet, and at 32 to 36 feet, which are probably the equivalent of that at 9 to 12 feet in this well. The distance between the two points is 1,300 feet.

The microfossiliferous mud beds are of the latest, *Pleistocene*, age. No beds of mud or clay of similar age occur in any of the borings between Pier No. 3 and the New Jersey shore.

No. 2.—Test Boring for Pier No. 2 (Second Pier from Pennsylvania Shore).

Diameter, 6 inches; depth below mean high water, 63 feet.

	Depth to river-bed	24 feet.	
4 feet.	Sand	24 to 28 "	
2 "	Black mud	28 " 30 "	
2 "	Sand	30 " 32 "	
4 "	Black mud	32 " 36 "	
5 "	Sand	36 " 41 "	
10 "	Sand and gravel	41 " 51 "	Cretaceous.
7 "	Sand	51 " 58 "	Cretaceous.
5 "	Sand and gravel	58 " 63 "	Cretaceous.
	Large gravel and broken stones on which this boring stopped	63 "	Cretaceous.

This record was made from an examination of specimens in the office of the railroad company's engineer, at Delair, N. J.

Afterward, upon sinking a caisson for the construction of this pier a tree-trunk was found at the depth of 52 feet.

No. 3.—Test Boring for Pier No. 3.

Diameter, 6 inches; depth below mean high water, 78 feet.

	Depth to river-bed	40 feet.	Cretaceous.
15 feet.	Sand	40 to 55 "	
3 "	Coarse gravel *and cobbles*	55 " 58 "	
5 "	Coarse gravel and white clay mixed	58 " 63 "	
3 "	Yellowish brown sand, finer	63 " 66 "	
8 "	Coarse sand	66 " 74 "	
4 "	Coarse gravel and large pebbles	74 " 78 "	

No. 4.—Caisson Record at Pier No. 4.

Depth below mean high water, 66 feet.

This pier carries the draw-span of the bridge, and is in the deepest part of the channel, which here lies near the New Jersey shore, the depth to the river bottom being 42 feet. The succession of the strata was obtained from the record kept by the railroad company's construction engineers during the sinking of the caisson preparatory to the building of the pier. It corroborates the borings made on either side at piers Nos. 3 and 5. The following is the record:

	Depth to river bed	42 feet.	
2 feet.	Gravel	42 feet to 44 "	
3 "	Gravel and cobbles	44 " 47 "	Cretaceous.
6 "	Gravel and sand	47 " 53 "	
4 "	Sand	53 " 57 "	
2 "	Sand, with a little clay	57 " 59 "	
7 "	Sand	59 " 66 "	

No. 5.—Test Boring for Pier No. 5 (First Pier from the New Jersey Shore).

Diameter, 6 inches; depth below mean high water, 95 feet.

	Depth to river bed	30 feet.	
1 foot.	Yellow clay	30 to 31 "	Cretaceous.
9 feet.	White clay	31 " 40 "	
11 "	White sand	40 " 51 "	
10 "	Gravel sand and white clay, mixed	51 " 61 "	
2 "	Coarse sand	61 " 63 "	
2 "	Fine gravel and sand	63 " 65 "	
4 "	Sand and clay	65 " 69 "	
6 "	White sand	69 " 75 "	
1 "	Coarse gravel and pebbles	75 " 76 "	
5 "	Sand and gravel	76 " 81 "	
5 "	Coarse gravel	81 " 86 "	
9 "	Gravel and sand	86 " 95 "	

No. 6.—Test Boring at Fisher's Point, near Delair, for Bridge Abutment, New Jersey Shore.

15 ft.	Sand and gravel	15 feet.	
2 "	Large coarse gravel	15 to 17 "	
2 "	Brown clay	17 " 19 "	
2 "	Clay and sand	19 " 21 "	Cretaceous.
3 "	Gravel	21 " 25 "	
3 "	White clay	25 " 28 "	
11 "	Coarse sand	28 " 39 "	
1 "	Fine gravel	39 " 40 "	
9 "	White clay	40 " 49 "	
11 "	Coarse sand	49 " 60 "	
5 "	White clay	60 " 65 "	
5 "	White clay with coarse heavy gravel and sand	65 " 70 "	
11 "	Coarse gravel	70 " 81 "	
15 "	White clay	81 " 96 "	
3 "	Clay and gravel mixed	96 " 99 "	
2 "	Sand	99 to 101 "	
1 "	Gravel	101 " 102 "	
13 "	Coarse gravel	102 " 115 "	
5 "	Coarse gravel	115 " 120 "	
2 "	White clay	120 " 122 "	
9 "	Fine gravel	122 " 131 "	
2 "	Gravel and sand	131 " 133 "	
1 "	White clay	133 " 134 "	
8 "	Gravel and sand	134 " 142 "	
17 "	Disintegrated rock	142 " 159 "	
	Stopped on hard rock		

It is noticeable that this boring does not show any red clay, from five to ten feet of which has been found in borings made at Pavonia, both at the pumping station on the river and at Stockton Water Company's plant on the C. & A. R. R. north of Pavonia station and also at the rail company's shops south of the same station.

The recent Alluvium deposit containing diatoms that is noted near the surface in borings Nos. 0, 1 and 2 is absent in this boring.

No. 6a.—Bored Well at Fisher's Point, Delair, for Water Supply.

Elevation, 5 feet; depth, 75 feet.

Immediately adjacent to the bridge abutment at Fisher's Point, George H. Orcutt put down a well to the depth of 75 feet. This well furnishes water to several houses in Delair occupied by the civil engineers connected with the railroad company. The strata penetrated are, as would be expected, the same as are recorded for the test (No. 6) made for the abutment. The well obtains a supply of excellent water from the coarse gravel noted in that record at the depth of 70 to 75 feet.

The details of strata, furnished by the men who drilled the well and corroborated by specimens received, are as follows:

Brownish sand	1 foot	to	10 feet.	
Coarse sand	10 feet	to	18 "	
Big bowlders	18	"	22 "	Cretaceous.
Brown sand	22	"	24 "	
Yellow clay	24	"	26 "	
White sand	26	"	33 "	
White clay	33	"	35 "	
White sand	35	"	43 "	
White clay	43	"	49 "	
Sand	49	"	52 "	
White clay	52	"	54 "	
Sand and coarse gravel	54	"	75 "	

No. 7.—Test Boring near Delair Station and on the West Side of the Camden and Amboy Roadbed.

Elevation, 15 feet; depth, 50 feet.

Another test boring was made by Geo. H. Orcutt near the Camden and Amboy Railroad and a short distance southwest of Delair sta-

tion, preparatory to the building of bridge abutments for the Sea Shore Railroad to pass over the Amboy tracks. We here insert the record. It is compiled from an examination of specimens of the borings in the office of the Pennsylvania Railroad Company's civil engineer, J. F. Stuart, at Delair station:

Yellow clayey loam	0 to 6 feet.	
Gravel	6 " 12 "	
White clay	12 " 14 "	Cretaceous.
Clay and sand	14 " 30 "	
White clay	30 " 33 "	
Clay and yellow sand	33 " 40 "	
Coarse white gravel	40 " 45 "	
Yellow clayey sand	45 " 47 "	
White clay	47 " 49 "	
Yellow sand and gravel	49 " 50 "	

No. 8.—Dug Well at Delair, for Water-Supply to Railroad Tank.

Elevation, 35 feet; depth, 33 feet.

This well was dug at the locality of the stump marked C on the accompanying map, plate X, and was commenced at the bottom of a rather extensive excavation made by the railroad engineers on the south of the right-of-way. The elevation of the floor of the excavation at this point is estimated at 35 feet.

We are informed that this well, after penetrating a bluish-clayey sand about one foot thick near the surface, was sunk to the depth of 33 feet entirely in gravel.

No. 9.—Bored Well at Delair.

Elevation, 40 feet; depth, 78 feet. Water rises within 40 feet of the surface. Revised from Annual Report, 1895.

This boring was commenced at the bottom of a dug well at the depth of twenty-five feet. The dug portion stopped near the base of a black clay stratum in which near the bottom the then owner of the property informs us that casts of "clams" were found and also the impression of a fish. The "clams" were undoubtedly the same forms of fresh-water mussels that have been so long known as occurring at the same horizon in what must be an extension of the

same black clay bed at Hatch's and Reeve's clay banks to the southward near Fish House station. Below we copy from the annual report for 1895, page 70, the record of the bored portion of this well. It was furnished by W. C. Barr, artesian well contractor.

	Thickness.	Depth.	
Dug well, bottom in black clay at....	25 feet	= 25 feet.	Fish House clay, &c.
Dry, coarse sand..........................	30 "	= 55 "	
Stiff white clay, fine white sand, then stiff white clay again..........	18 "	= 73 "	Raritan Plastic Clays. Cretaceous.
Coarse sand and heavy gravel.........	5 "	= 78 "	

This well supplies excellent water which rises within forty feet of the surface or about to tide-level. It is obtained from the yellowish-white gravels that are characteristically interstratified within the plastic clays.

SPECIAL NOTES ON TEST BORINGS NOS. 10 TO 42, AT DELAIR AND FISH HOUSE, IN SUPERFICIAL STRATA OVERLYING CRETACEOUS PLASTIC CLAYS.

Nos. 14, 18, 33, 34 and 37 also enter the underlying Cretaceous strata.

In acquiring the right of way over valuable clay land for the new sea-shore connection for the Pennsylvania Railroad from Broad street station, Philadelphia, via Frankford Junction, Delaware river bridge, Delair and Haddonfield and in estimating the compensation to be paid therefore, a number of test-borings were made at Delair, along two lines, one on the main route eastward from the River road, and the other southward from Browning's lane, on a projected south branch, since abandoned, but then intended to connect below Fish House station with the Camden and Amboy route.

The specimens from this entire series of borings, except Nos. 41 and 42, have been courteously placed in our hands by the engineers in charge of the construction of the railroad. They are located on the map by Nos. 10 to 42. The detailed records of each which follow have been made from an examination of these and some other duplicate specimens. Moreover, these records are unusually reliable, having been made under the supervision of the railroad company's civil engineers. The exact elevation at each well was accurately noted, while the thickness and depth of each specimen was carefully attached thereto, a sample being taken for every change.

Borings Nos. 10 to 19 on the east or main line pass through a succession of sands, clays and sandy clays of an orange-yellow or yellowish-brown color, and also enter a medium coarse gravel, in color and grain apparently identical with that noted below as occurring beneath the black clay on the south branch.

Of these wells No. 14 passed beyond the gravel into white, stiff clay and white, sandy clays at the depth of about ten feet, the elevation of the surface being fifty-four feet. Between the depths of twenty-four and thirty-four feet we especially note a solid bed of fine white, plastic clay. All the beds in this boring below about ten feet belong to the Raritan division of the Cretaceous.

Of the borings Nos. 21 to 40, on or near the line of a projected south branch afterward abandoned, Nos. 29, 30 and 31 were made on the floor of the excavation, and immediately passed into a medium fine, yellowish gravel, known to be cross-bedded from pits dug into it elsewhere from the same floor at the points marked on the map H G and F G. The remainder of this group of borings were upon the higher ground surrounding the excavation, and most of them after passing through the surface sands penetrated a greater or less thickness of yellowish clay, and then of dark or black clay, and thence passed into the same yellowish gravel noted as occurring below the floor of the excavation in the three borings above named.

Three other borings, however, of this group, Nos. 33, 34 and 37, which were made on the southern margin of the field near to and on the line of the Cove road, and toward the River road, after penetrating a thin layer of the upper, orange-yellow member of the Fish House clay bed, soon entered undoubted Cretaceous, white plastic clays, whose upper surface is at a higher level than the lower portion of the black clays, showing that the Fish House black clay bed and underlying gravel abuts against the Cretaceous, white clays with decided unconformity.

No. 10.—Test Boring at Delair, 375 Feet East of the River Road.

Elevation, 63 feet; depth, 45 feet.

1. Surface sand	4	feet =	4 feet.
2. Sand and gravel	6½	" =	10½ "
3. Reddish-yellow clay	½	" =	11 "
4. Sandy clay and gravel	2	" =	13 "
5. Sand lighter in color	5½	" =	18½ "
6. Reddish-yellow clay, like No. 3	5	" =	23½ "

7. Dark-black clay	1½ feet	= 25	feet.
8. Clayey sand, dark color	3 "	= 28	"
9. Black clay	7½ "	= 35½	"
10. Reddish fine gravel	4 "	= 39½	"
11. Black sand	4½ "	= 44	"
12. Reddish, clayey gravel, as No. 10	1 "	= 45	"

No. 10K.—Test Boring at Delair, within 1 Foot of No. 10.

Elevation, 63 feet; depth, 47 feet.

This record has been made from an examination of borings in the possession of Wm. H. Knowles:

1. Surface sand	2 feet	= 2	feet.
2. Clayey sand	8 "	= 10	"
3. Gravelly clay	2 "	= 12	"
4. Deep-yellow clay	7 "	= 19	"
5. Orange-yellow clay	3 "	= 22	"
6. Dark-brown clay	16 "	= 38	"
7. Orange-yellow clay	3 "	= 41	"
8. Orange colored sand, fine	1 "	= 42	"
9. Blue, clayey sand	1 "	= 43	"
10. Blue clay	4 "	= 47	"

No. 11K.—Test Boring at Delair, 200 Feet East of Nos. 10 and 10K.

Elevation, 70 feet; depth, 47 feet.

Record made from inspection of specimens shown by W. R. Knowles.

Soil	1 foot	= 1	foot.
Orange red clay	3 feet	= 4	feet.
Orange-yellow clay	5 "	= 9	"
Medium coarse gravel	7 "	= 16	"
Orange-red clay	4 "	= 20	"
Yellow sandy clay	2 "	= 22	"
Darker yellow clay, fine	2 "	= 24	"
Fine gravel	2 "	= 26	"
Dark yellow clay	2 "	= 28	"
Orange-yellow clay	2 "	= 30	"
" " "	4 "	= 34	"
" " sand	2 "	= 36	"
" " clay	2 "	= 38	"
" colored gravel, medium coarse	2 "	= 40	"
" " sand, medium fine	7 "	= 47	"

No. 11.—Test Boring at Delair, 300 Feet East of Nos. 10 and 10K.

Elevation, 68 feet; depth, 44 feet.

Gravel	4½ feet	= 4½ feet.
Orange-red clay	7½ "	= 12 "
Yellow fine gravel	2 "	= 14 "
Orange-yellow clay	3 "	= 17 "
" " clayey sand	3 "	= 20 "
Reddish clay	3 "	= 23 "
Clay (no sample)	1 "	= 24 "
Fine yellow gravel	8 "	= 32 "
" " sandy clay	2 "	= 34 "
Reddish yellow sand	1½ "	= 35½ "
" " " slightly coarser	8½ "	= 44 "

No. 12.—Test Boring at Delair, 300 Feet East of No. 11.

Elevation, 67 feet; depth, 23 feet.

Soil and heavy gravel, with pebbles	1½ feet	= 1½ feet.
Yellowish-red clay	5½ "	= 7 "
Yellowish-red fine gravel	8 "	= 15 "
Yellowish-red fine clay	3 "	= 18 "
Yellowish-red fine gravel, lighter in shade	½ "	= 18½ "
Yellowish-red sandy clay	1½ "	= 20 "
Fine gravel or sand, lighter shade	1½ "	= 21½ "
Gravel	½ "	= 22 "
Fine sand	1 "	= 23 "

No. 12K.—Test Boring at Delair, 20 Feet East of No. 12.

Elevation, 68 feet; depth, 32 feet.

Record made from borings shown by Wm. H. Knowles, artesian well contractor:

Yellowish-colored loam	2 feet	= 2 feet.
Reddish-yellow gravelly clay	3 "	= 5 "
Yellowish gravelly clay	5 "	= 10 "
Lighter-yellow clay, with large gravel in it	16 "	= 26 "
Ironstone, 6 inches	½ "	= 26½ "
Orange-colored sand	5½ "	= 32 "

No. 13.—Test Boring at Delair, 300 Feet East of No. 11.

Elevation, 70 feet; depth, 12½ feet.

Soil	1	foot	= 1	foot.
Yellowish-red sand	1	"	= 2	feet.
Ironstone crust, 4 inches.				
Reddish-yellow clay	1¼	"	= 3¼	"
Reddish-yellow sandy clay	2¾	"	= 6	"
Reddish-yellow sandy clay, lighter in shade	6½	"	= 12½	"

No. 13K.—Test Boring at Delair, Within 1 Foot of No. 12.

Elevation, 70 feet; depth, 25 feet.

Record made from examination of specimens shown by W. H. Knowles.

Soil	1	foot	= 1	foot.
Reddish clay	4	feet	= 5	feet.
Orange-yellow sand	3	"	= 8	"
Orange-red sand	5	"	= 13	"
Orange-yellow sand	12	"	= 25	"

No 14.—Test Boring at Delair, 300 Feet East of No 13.

Elevation, 54 feet; depth, 39 feet.
Ten feet of white, plastic clay at 24 to 34 feet.

Soil	2	feet	= 2	feet.	
Gravel and reddish-yellow sandy clay	1½	"	= 3½	"	
Reddish-yellow clay and medium coarse gravel	1	"	= 4½	"	
Reddish-yellow fine gravel or coarse sand	4	"	= 8½	"	
Lighter-colored fine sand	½	"	= 9	"	
White plastic clay	½	"	= 9½	"	Raritan Cretaceous.
White fine sand	1½	"	= 11	"	
White plastic clay	1½	"	= 12½	"	
White fine sand	4½	"	= 17	"	
White sand, coarser	6	"	= 23	"	
Yellow coarse sand or gravel	½	"	= 23½	"	
White plastic clay	11	"	= 34½	"	
White clay (no specimen)	2½	"	= 37	"	
White sand	2	"	= 39	"	

The engineer's profile of these test borings shows that the Fish House clays have disappeared before reaching eastward to the location of this well. A few inches of white clay are noted at the depth of about ten feet, while ten feet of white clay occur between the depths of 24 and 34 feet. All of this section below the depth of about ten feet is characteristically the Cretaceous, white, plastic clay and sandy clays, and belongs to the Raritan division thereof.

No. 14K.—Test Boring at Delair, 46 Feet East of No. 14.

Elevation, 46 feet; depth, 16 feet.

This record was made from borings in the possession of Wm. H. Knowles, and being in a hollow between test borings Nos. 14 and 15, and therefore on lower ground, especially completes our section.

Brownish sand	4	feet	= 4	feet.
Yellow clay	1	"	= 5	"
Light orange-yellow sand	11	"	= 16	"

No. 15.—Test Boring at Delair, 300 Feet East of No. 14.

Elevation, 56 feet; depth, 28 feet.

1. Yellowish-red sand	2	feet	= 2	feet.
2. Yellowish-red gravel	4	"	= 6	"
3. Yellowish-red gravel, lighter shade	1	"	= 7	"
4. Yellowish-red gravel, as No. 2	1	"	= 8	"
5. Yellowish-red sand, lighter shade	3	"	= 11	"
6. Yellowish-gray sand	7½	"	= 18½	"
7. Brownish sand	1½	"	= 20	"
8. Brownish sand	1	"	= 21	"
9. Gray sand	4½	"	= 25½	"
10. Fine sand	½	"	= 26	"
11. Coarse sand	1	"	= 27	"
12. Fine sand	1	"	= 28	"

No. 16.—Test Boring at Delair, 300 Feet East of No. 15.

Elevation, 64 feet; depth, 20 feet.

Soil	2	feet,	2	feet.
Reddish gravel and clay	10½	"	12½	"
Light yellow sand	3½	"	16	"
Light yellow sand	4	"	20	"

No. 17.—Test Boring at Delair, 350 Feet East of No. 16.

Elevation, 58 feet; depth, 21 feet.

Soil	½ foot,	½ foot.
Reddish-yellow clayey sand	12½ feet,	13 feet.
Orange-yellow sand	1½ "	14½ "
Orange-yellow clay, 2 inches	— "	— "
Orange-yellow gravel or coarse sand	3½ "	18 "
Fine gravel, slightly lighter shade	3 "	21 "

No. 18.—Test Boring at Delair, 350 Feet East of No. 17.

Elevation, 36 feet; depth, 21 feet.

Soil	2½ feet	= 2½ feet.
Ironish-yellow fine gravel	4 "	= 6½ "
Light-colored clay	½ "	= 7 "
Orange-yellow sand	5 "	= 12 "
Orange-yellow sand, coarser	2½ "	= 14½ "
Medium coarse sand, lighter color	2 "	= 16½ "
Finer sand, lighter color	4½ "	= 21 "

The last stratum closely resembles the white sands of the Plastic clay formation.

No. 19.—Test Boring at Delair, 300 Feet East of No. 18.

Elevation, 45 feet; depth, 20 feet.

Soil	1 foot	= 1 foot.
Orange-yellow coarse sand or fine gravel	7 feet	= 8 feet.
Orange-yellow coarse gravel	12 "	= 20 "

No. 20.—Shallow Dug Well near Fish House.

Elevation, 5 feet; depth, 20 feet. (?)

This well was dug inside the terra-cotta works of Augustus Reeve. Its depth is probably not over 20 feet. It passed through a thin bed of white clay, probably of the plastic clay series, before obtaining its supply of water.

No. 21.—Test Boring South of Delair, on the South Line of Browning's Lane.

Elevation, 34 feet; depth, 20 feet.
Record made from specimens in the possession of Hatch Bros., and correlated with the railroad company's duplicate series.

1. Soil	1 foot	=	1 foot.
2. Fine gravel	3 feet	=	4 feet.
3. Yellow fine sand	3 "	=	7 "
4. Gravel	3 "	=	10 "
5. Orange-yellow sand	2 "	=	12 "
6. Orange-yellow coarse sand	2 "	=	14 "
7. Orange-yellow sand and coarse gravel	2 "	=	16 "
8. Orange-yellow sand, fine	4 "	=	20 "

No. 22.—Test Boring South of Delair, 100 Feet South of No. 21.

Elevation, 35 feet; depth, 18 feet.
Record made from specimens in the possession of Hatch Bros., and correlated with the railroad company's duplicate series.

1. Soil	1 foot	=	1 foot.
2. Yellow sand	1 "	=	2 feet.
3. Orange-yellow sand or gravel	2 feet	=	4 "
4. Orange-yellow sand and heavy gravel	4½ "	=	8½ "
5. Brownish-yellow clay	3½ "	=	12 "
6. Orange-yellow coarse sand or gravel	2½ "	=	14½ "
7. Orange-yellow sand, lighter color	3½ "	=	18 "

No. 23.—Test Boring South of Delair, 175 Feet East of No. 22.

Elevation, 33 feet; depth, 13 feet.

Record made from samples in the possession of Hatch Bros., and correlated with the railroad company's duplicate series:

1. Soil	1 foot	=	1 foot.
2. Fine yellow gravel	2 feet	=	3 feet
3. Fine yellow gravel and coarse sand	3 "	=	6 "
4. Yellowish clay	7 "	=	13 "

No. 24.—Test Boring South of Delair, 300 Feet South of No. 23.

Elevation, 34 feet; depth, 18 feet.

Record made from specimens shown by Hatch Bros., and correlated with the railroad company's duplicate series:

1. Soil	2½ feet	=	2½ feet.
2. Sand or fine gravel	2 "	=	4½ "
3. Dark clay	7½ "	=	12 "
4. Black sandy clay	1½ "	=	13½ "
5. Orange-yellow clay	3½ "	=	17 "
6. Orange-yellow coarse sand or fine gravel	1 "	=	18 "

No. 25.—Test Boring South of Delair, 300 Feet South of No. 24.

Elevation, 43 feet; depth, 28 feet.

Record made from specimens shown by Hatch Brothers, and correlated with the railroad company's duplicate series.

1. Soil	1 foot	=	1 foot.
2. Orange-yellow sand	1½ feet	=	2½ feet.
3. Orange-red sand	2 "	=	4½ "
4. Orange-colored gravel or coarse sand	½ "	=	5 "
5. Orange-red irony sand	½ "	=	5½ "
6. Orange-yellow sand	½ "	=	6 "
7. Fine gravel and sand, lighter color	½ "	=	6½ "
8 Sand and gravel and large pebbles	1½ "	=	8 "
9. Dark clay	14 "	=	22 "
10. { Ironstone; Orange-red clay; Ironstone crust, 6 inches; Orange-yellow gravel }	2 "	=	24 "
11. Yellowish-gray gravel	½ "	=	24½ "
12. Yellowish-gray gravel, lighter shade	3½ "	=	28 "

No. 26k.—Test Boring South of Delair, 42 Feet South of No. 25.

Elevation, 45 feet; depth, 28 feet.

Record from samples shown by W. H. Knowles.

Soil	1 foot	=	1 foot.
Sand	2 feet	=	3 feet.
Sand	1 "	=	4 "

Yellow sandy clay	3 feet	= 7	feet.
Fine gravel	2 "	= 9	"
Yellow clay	6 "	= 15	"
Black clay	8 "	= 23	"
Orange-yellow clay	1 "	= 24	"
Ironstone crust	½ "	= 24½	"
Orange-yellow sand	3½ "	= 28	"

No. 27.—Test Boring South of Delair, 300 Feet South of No. 25.

Elevation, 52 feet; depth, 34 feet.

Record made from samples shown by Hatch Brothers and correlated with the railroad company's duplicate series.

1. Soil	2 feet	= 2	feet.
2. Orange-red gravel	2 "	= 4	"
3. Light-yellow gravel	4½ "	= 8½	"
4. Gravel	½ "	= 9	"
5. Orange-red clayey sand	2 "	= 11	"
6. Dark clay	21½ "	= 32½	"
7. Yellowish gravel	1½ "	= 34	"

No. 28.—Test Boring South of Delair, 200 Feet South of No. 27.

Elevation, 52 feet; depth, 35 feet.

Record made from specimens shown by Hatch Brothers and correlated with the railroad company's duplicate series.

The superficial sands and gravels of the preceding records had been stripped from the surface of the clay at the location of this well. The boring commenced on the top of the clay. The elevation noted is that of the top of the clay and not of the original surface, which must have been some five to eight feet higher.

1. Yellowish clay	8½ feet	= 8½	feet.
2. Dark clay	15½ "	= 24	"
3. Dark sandy clay	7½ "	= 31½	"
4. Ironstone crust, &c	2½ "	= 34	"
5. Light-colored sand	1 "	= 35	"

No. 29.—Test Boring South of Delair, 100 Feet South of No. 28.

Elevation, 25 feet; depth, 7 feet.

Record made from samples shown by Hatch Brothers and correlated with the railroad company's duplicate series.

This boring was made on the floor of the pit, most of the black clay of the previous records having been removed.

Black clay	4 feet	= 4 feet.
Orange-yellow clay	1 "	= 5 "
Ironstone crust, say 6 inches.		
Sand and gravel	2 "	= 7 "

No. 30.—Test Boring South of Delair, 140 Feet South of No. 29.

Elevation, 26 feet; depth, 8 feet.

Record obtained from the railroad company's profile.

Like the preceding well, this one also was located on the floor of the pit from which nearly all the clay had been removed.

Yellowish clay	1 foot	= 1 foot.
Sand and gravel	7 feet	= 8 feet.

No. 31.—Test Boring South of Delair, 95 Feet South of No. 30.

Elevation, 31 feet; depth, 21 feet.

This boring was also made from the floor of the excavation. An examination of specimens furnished by the railroad company gives us the following record:

Surface sand	10 feet,	10 feet.
Orange-yellow sand	3½ "	13½ "
Orange-yellow sand, lighter in shade	7½ "	21 "

No. 32.—Test Boring South of Delair, near Fish House Station, 485 Feet South of No. 31.

Elevation, 21 feet; depth, 6 feet.

This boring, like the three borings previously noticed, was made from the floor of the excavation. It commenced on the ironstone crust, which has a thickness of about three to six inches, and then penetrated a yellowish gravel to the depth of six feet.

No. 33.—Test Boring South of Delair, Near Fish House Station, 190 Feet Southwest of No. 32.

Elevation, 41; depth, 36 feet.

Record made from an examination of the railroad company's borings.

Soil	1 foot	1 foot.	
Orange-red sand	2 feet	3 feet.	
Orange-red sandy clay	1½ "	4½ "	
Orange-red clayey sand	3 "	7½ "	
Orange-yellow sandy clay	2½ "	10 "	
Orange-red sand	5 "	15 "	
Dark clay	1 "	16 "	
Orange-yellowish clay	1 "	17 "	
Orange-reddish yellow sand, fine	2 "	19 "	
Orange-reddish yellow sand, fine	8 "	27 "	
a. Light-colored sand, coarse	3 "	30 "	Raritan Cretaceous.
b. Light-colored sand, finer	1 "	31 "	
c. Light-colored sand, much coarser than *a*	3 "	34 "	
d. Fine white sand	2 "	36 "	

No. 34.—Test Boring South from Delair, Near Fish House Station, on the Cove Road, 90 Feet Southwest of No. 33.

Elevation, 36 feet; depth, 28 feet.

Record compiled from samples of the boring furnished by the railroad company.

Soil	2 feet,	2 feet.	
Fine yellow sand	1 "	3 "	
Orange-yellow gravel	1 "	4 "	
Orange-yellow sandy clay	2 "	6 "	
Coarse gravel	1 "	7 "	
Orange-yellow clay	2 "	9 "	
Light yellowish white clay	5½ "	14½ "	Raritan Cretaceous.
White clay	5½ "	20 "	
White clay	4 "	24 "	
White clay	1 "	25 "	
White sand	3 "	28 "	

No. 35K.—Test Boring South from Delair, Near Fish House Station, and Near No. 35.

Elevation, 44 feet; depth, 33 feet.

This boring was made by W. H. Knowles, who kept a careful record, which he furnished to Augustus Reeve. The latter courteously placed the same in our hands. It is as follows:

Specimen Number.	Kinds of Material.	Thickness of Strata.	Total Depths.
1.	Top soil	3½ feet.	3½ feet.
2.	Moulding sand	1½ "	5 "
3.	Sand	4 "	9 "
4.	Very fine sand	4 "	13 "
5.	Gravel	1½ "	14½ "
6.	Blue clay	5½ "	20 "
	Ironstone crust	6 inches.	20½ "
7.	Dark sand	2½ feet.	23 "
8.	Fine light sand	4 "	27 "
9.	Dark sand	3 "	30 "
10.	Light sand and gravel	3 "	33 "

No. 35.—Test Boring South of Delair, Near Fish House Station, 125 Feet South of No. 32.

Elevation, 41 feet; depth, 30 feet.

Record made from an examination of the railroad company's borings.

Soil	1 foot	1 foot.
Orange-red sand	2 feet	3 feet.
Orange-red clay	1 "	4 "
Orange-red sand, fine	7½ "	11½ "
Orange-red sand, coarser	1 "	12½ "
Black clay	8 "	20½ "
Iron-red sand	½ "	21 "
Gravel	5 "	26 "
Sand	4 "	30 "

No. 36.—Test Boring South of Delair, Near Fish House Station, 65 Feet South of No. 35.

Elevation, 42 feet; depth, 19 feet.

Record compiled from an examination of borings furnished by the railroad company's engineer:

Soil	1 foot,	1 foot.
Orange-yellow sand	2 feet,	3 feet.
Orange-red sand	2 "	5 "
Black clay	1 "	6 "
Iron-red sand	1 "	7 "
Dark clay	1 "	8 "
Orange-yellow gravel, with large pebbles	2 "	10 "
Orange-yellow clay	1 "	11 "
Orange-yellow clayey sand	2 "	13 "
Black sandy clay	6 "	19 "

No. 37.—Test Boring South of Delair, near Fish House Station, on the Cove Road, 155 Feet South of No. 36.

Elevation, 35 feet; depth, 30 feet.

Record made from an examination of the railroad company's specimens of the borings.

Soil	2 feet	2 feet.	
Orange-red sand	1 "	3 "	
Orange-red gravel, with pebbles	2 "	5 "	
Orange-red sandy clay	1 "	6 "	
Fine yellow clay	2 "	8 "	
Course gravel	9 "	17 "	
Fine sand, light in color	1 "	18 "	
Yellow sandy clay	5 "	23 "	
Orange-colored sand	2 "	25 "	
White clay, sandy	4 "	29 "	Raritan Cretaceous.
White clayey sand	1 "	30 "	

No. 38.—Test Boring South of Delair, Near Fish House Station, 150 Feet South of No. 35.

Elevation, 40 feet; depth, 38 feet.

Record compiled from an examination of specimens furnished by the railroad company:

Soil	1 foot	= 1 foot.
Yellow sand	5 feet	= 6 feet.
Fine sand	1½ "	= 7½ "
Gravel, yellow	3 "	= 10½ "
Yellow clay	1 "	= 11½ "
Black clay	3 "	= 14½ "
Yellow clay	1 "	= 15½ "
Iron-rusty sand	1 "	= 16½ "

Reddish-yellow fine gravel	2½ feet	= 19	feet.
Yellow sand	2 "	= 21	"
Reddish-yellow sand	5 "	= 26	"
Yellow sand and gravel	5 "	= 31	"
Whitish sand	7 "	= 38	"

No. 38K.—Test Boring South from Delair and Near Fish House Station, Adjacent to No. 38.

Elevation, 40 feet; depth, 20 feet.

This boring was made by W. H. Knowles, who kept a careful record which he furnished to August Reeve, for whom the work was done, and who kindly placed the record in our hands. It is as follows:

Number of Specimen.	Kind of Material.	Thickness of Strata.	Total Depths.
1.	Top soil	3½ feet.	3½ feet.
2.	Moulding sand	1½ "	5 "
3.	Sand	2 "	7 "
4.	Very fine sand	1 "	8 "
5.	Gravel	3 inches.	
6.	Yellow clay	5½ feet.	13½ "
7.	Gravel	6½ "	20 "

No. 39.—Test Boring South of Delair, Near Fish House Station, 75 Feet South of No. 38.

Elevation, 39 feet; depth, 15 feet.

Record made from an examination of borings made for the railroad company:

Soil	1 foot	= 1	foot.
Fine yellow sand	3 feet	= 4	feet.
Orange-yellow clay	1 "	= 5	"
Gray sand	4 "	= 9	"
Orange-red clayey sand	1 "	= 10	"
Greenish clay	1 "	= 11	"
Yellow clay	½ "	= 11½	"
Black clay	2 "	= 13½	"
Light or colored clay	1½ "	= 15	"

No. 40.—Test Boring South of Delair, Near Fish House Station, 100 Feet South of No. 39, on the Cove Road.

Elevation, 34 feet; depth, 15 feet.

Surface sand	1 foot	1 foot.
Orange-yellow sandy clay	2 feet	3 feet.
Orange-red clayey sand	1 "	4 "
Gravel, some large pebbles	2 "	6 "
a. Orange-Yellow, sandy clay	1 "	7 "
b. Yellow clay, lighter in shade than *a*	2 "	9 "
Orange-yellow sand	6 "	15 "

Nos. 41 and 42.—Test Borings South of Delair, Near Fish House Station.

Fish House clay absent.

These borings were made 125 feet and 225 feet, respectively, southwest of No. 38. They were put down to a depth of but a few feet only in sand and gravel, sufficient, however, to show that the yellow and black clays of the Fish House had run out before reaching so far to the southward. No specimens were obtained of these two borings.

No. 44.—Bored Well at Delair, River Road South of Velde Avenue.

Elevation, 57 feet; depth, 60 feet.

This well has a depth of 60 feet. In the upper portion 14 feet of black clay (Fish House clay) was penetrated. Water was obtained at the depth of 50 to 60 feet in a mixture of white sand and gravel with large pebbles. The water horizon is probably Cretaceous, while all, or nearly all, above is of a much later age.

No. 45.—Bored Well at Delair, at the Public Hall, River Road South of Engard Avenue.

Elevation, 35 feet; depth, 60 feet.

This well probably enters the Cretaceous in the lowest 10 or 15 feet. We could not obtain information respecting it except as to depth.

No. 46.—Bored Well at Delair, Velde Avenue West of Holman Avenue.

Elevation, 60 feet; depth, 49 feet.

As we write, this well is being bored. It was commenced in the bottom of a dug well with a depth of about 20 feet. It almost immediately passed into the Fish House black clay bed and into gravel beneath, and had not at the depth attained of 49 feet encountered any strata resembling those of the Cretaceous.

Its record, as furnished us by the men who drilled it, is:

Bottom of dug well on black clay at the depth of	20 feet,	20 feet.
Black clay	17 "	37 "
Iron-stone crust	1 "	38 "
Reddish-yellow sand and clayey sand	11 "	49 "

No. 47.—Bored Well at Delair, Velde Avenue East of Holman.

Elevation, 60 feet; depth, 65 feet.

This boring is said to have passed through black clay, undoubtedly the Fish House beds, and to have obtained water at the depth of 60 to 65 feet in a coarse, white sand, probably Cretaceous.

No. 48.—Bored Well at Delair, Delair Avenue West of Day Avenue.

Elevation, 32 feet; depth, 43 feet.

This well is on lower ground than any of the wells we have noted west of the Camden and Amboy Railroad and north of Derousse avenue.

It has a depth of 43 feet, and is said to have passed through yellow and black clays shortly beneath the surface. The water-supply at the bottom evidently is from the same horizon as that supplying Well No. 47, the difference in depth being mainly due to the difference in elevation.

The clays of the upper portion, probably, represent nearly the most northern extension of the Fish House beds, the water horizon being below them in the Cretaceous.

No. 49.—Bored Well at Delair, South Side Derousse Avenue, East of River Road.

Elevation, 70 feet; depth, 68 feet.

This well is reported to have passed through considerable yellowish clays before reaching a water-bearing *white sand* at the base, at the depth above named. It is but about 300 feet north of test wells Nos. 10 and 10K, and is on ground about seven feet higher. The two last-named show by the borings we have on hand that they did not pass below the Fish House clays and underlying yellowish gravel. This well (No. 49) probably passed into Cretaceous strata at about the depth of 60 feet.

No. 50.—Bored Well at Delair, Curtiss Avenue West of Barnard Avenue.

Elevation, 35 feet; depth, 60 feet.

This well is said to have been bored entirely in sand to the depth of 60 feet, finding water in a white gravel at the bottom.

No. 51.—Bored Well at Delair, Curtiss Avenue, East of Barnard Avenue.

Elevation, 35 feet; depth, 60 feet.

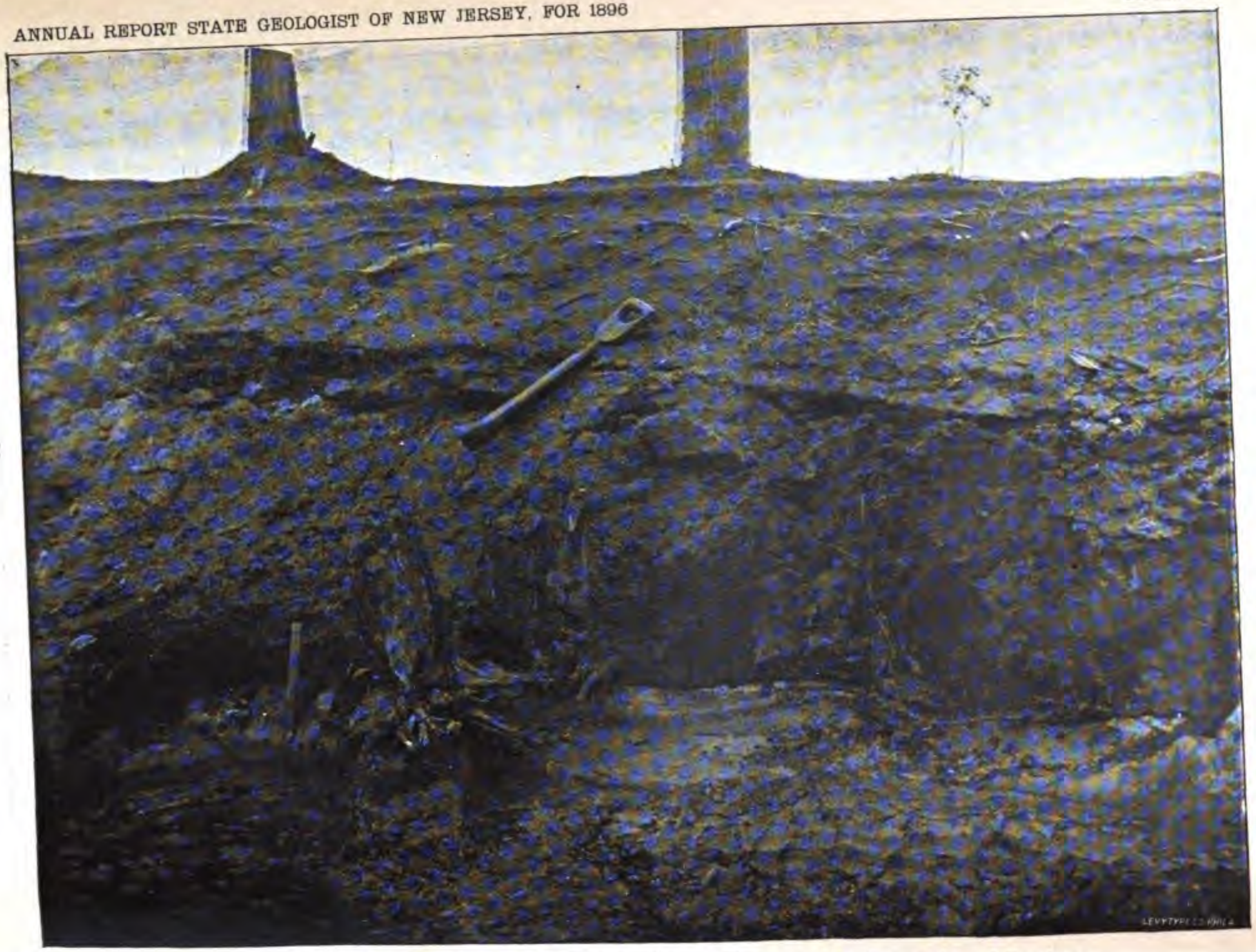
This is a driven well, put down to a depth of 60 feet. White clay, probably Cretaceous, plastic clay, is said to have been passed through in the lower portion before reaching a water horizon.

No 52.—Bored Well at Delair, West Side of Railroad Avenue, North of Curtiss Avenue.

Elevation, 22 feet; depth, 37 feet.

This well is said to be thirty-seven feet deep and is said to have missed the black clay, being beyond its western margin, and to have been sunk mostly through sand and gravel.

PLATE XII



Section at Delair, N. J. Clump of Buried Tree Stumps Uncovered by Depression of Roadway.

Buried Tree Stump, Delair, N. J. Largest One of Clump seen on Plate XII. Circumference at top, 14 inches. Length to the Branching of the Roots, 1½ feet.

BURIED TREE-TRUNKS AT DELAIR IN GRAVELS ABOVE THE FISH HOUSE CLAY BEDS AND OF MORE RECENT AGE.

The extensive excavations made by the railroad company at Delair reveal, upon the farm lately owned by Eli W. Browning, a surface deposit consisting of five feet, more or less, of a fine gravel, almost without a single pebble as large as a pea. This gravel at the cross-roads in Delair rests directly upon the brownish-yellow colored upper stratum of the Fish House black clay, but southward and southeastward there intervenes between the surface-gravel and the clay, first and uppermost, two to four feet of a fine sand with a slightly greenish tinge and somewhat clayey consistency; then beneath this a bed only a foot or so in thickness of yellow coarse gravel, with large pebbles and some cobbles.

The same fine, surface gravel, the somewhat clayey fine sand and the heavy gravel occur in the same order one-half mile southward, on the Reeve property, at Fish House. They may there be seen in the northern end of the cut through the hill, near the Cove road, to again rest directly upon the black Fish House clay.

Five different points scattered over one field of the Browning farm were pointed out to the writer by several informants, where in consequence of the excavations referred to there had been found in the superficial gravel, a few feet from the surface, buried tree-stumps in an upright position. The stumps had been removed from most of these spots by a steam shovel and had probably been reburied in the railroad embankment made close by. At one point on the side of a lane which had been depressed to pass under an intended railroad siding, since abandoned, there was early last spring to be seen still remaining a single stump, and thirty feet therefrom a group of four stumps which, by a little additional digging into the side of the bank, was increased to six. This group is shown in place on plate XII, which is a reproduction from a photograph made at the time by H. C. Borden, who kindly loaned the negative for our use. The largest stump, which was really a double one, representing, evidently, two trees joined at the base, is shown in the photogravure, plate XIII, which also was made from a negative of H. C. Borden's. It measured fourteen inches around near the top and is one and a half feet long to the branching of the roots. This specimen is deposited in the Survey's collections at Trenton. When taken from the bank the tendrils of the roots were still clinging thereto; this may be seen in the picture.

The wood is in a remarkably good state of preservation, and can be worked with either knife, saw or plane as readily as that from any tree of the forests of to-day.

E. W. Browning states that until within a few years when underdrains were put in, the area where the various stumps occurred was more or less swampy most of the time. Indeed, the remarkable preservation of the wood unchanged is probably because the strata in which they were imbedded has been continuously saturated with water, held therein as in a reservoir by the impervious Fish House clays beneath. The trees evidently grew upon the top of the sand bed, since the branching of the roots occurred exactly at the junction of the sand and the overlying fine gravel, the roots ramifying downward into the sand and the trunks being imbedded in the gravel. From an excavation, not now exposed, but which had been made near by below the level of the depressed land, we are able to record the following succession of strata, the elevation of the surface being nearly forty feet:

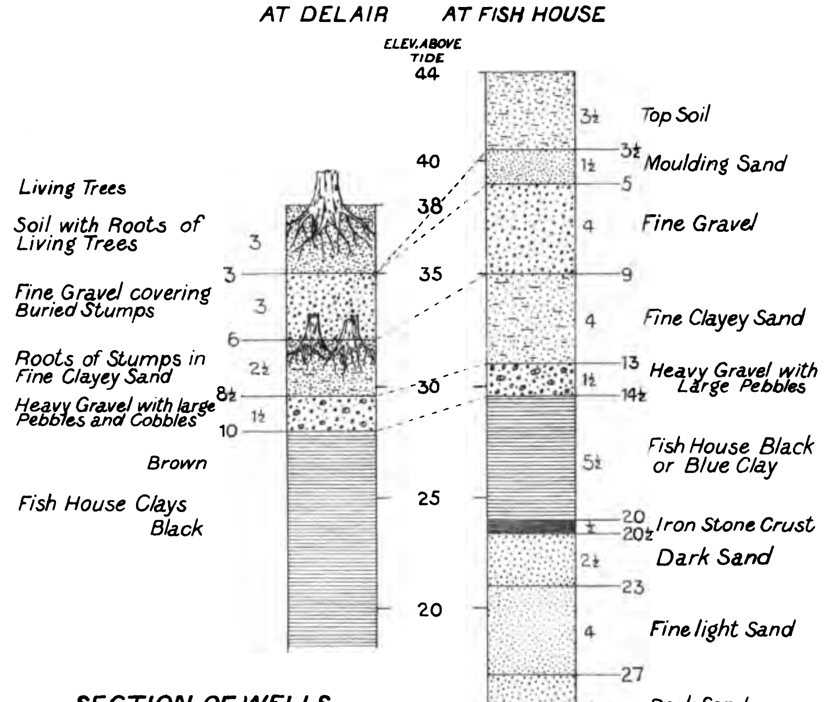
Soil, with roots of living trees, which did not pass below this	3 feet.
Fine gravel, without pebbles; buried *tree-stumps* in this	3 "
Greenish-gray, slightly clayey fine sand; *roots* of buried tree-stumps in this	2½ "
Reddish-yellow hard gravel, almost hard-pan, with large pebbles and sometimes cobbles	1½ "

Below this are the Fish House clays, brownish on top and black beneath.

The same succession of strata, as already stated, can be seen one-half mile southward, in the cutting through the hill immediately east of Fish House station and north of the Cove road. The uppermost bed of fine gravel is here some nine feet thick, with a one and one-half foot layer of moulding sand slightly above the middle. The fine, greenish-gray sand is four feet thick and the underlying heavy gravel again about one foot thick, and at the north end of the cut rests immediately upon the black Fish House clay, which is well shown in Reeve's pit adjacent. Buried stumps have not, however, been reported from this locality.

Plate XIV shows the correspondence of the stratification at the two points noted, viz., at Delair and Fish House.

The group of stumps above figured and described, and the single stump near by, have since been removed. As we go to press, there,



SECTION OF WELLS
AT
DELAIR & FISH HOUSE, CAMDEN CO.

BY LEWIS WOOLMAN

however, still remain, some 300 feet westward, two other upright buried stumps, one of which is eighteen inches in diameter and two feet high. This stump, like the others, was buried in the fine surface gravel, three feet of which was above it and two feet around it. The bed of sand on and in which the others had grown appears to be a lenticular bed, and had run out before reaching so far eastward, so that these two stumps were just beyond its margin, and their roots grew downward directly into the heavy underlying gravel, there being packed among the roots heavy hard sandstone cobbles ranging from two to fifteen pounds in weight.

Microscopical examinations of preparations of thin transverse, radial and tangential sections from the trees in the clump and from the two trees last noted have been made. These sections demonstrate that the trees are coniferous. Resin cells, with the resin still remaining, can be seen with moderate magnifying power in the tangential sections, while with high magnification the radial sections show the peculiar bordered pits known as tracheids and which are characteristic of conifers. The pits are arranged in a single row on the wall of each longitudinal tube.

We regard the thin bed of heavy gravel beneath the fine clayey sand as of Pensauken age. The fine sand and overlying fine gravels are, of course, of a slightly later age, but whether of a late Pensauken time or of time still later than Pensauken, it may not, perhaps, be safe to be too positive. We, however, incline to the latter view, at least for the fine sand, in which case it may be of Jamesburg age. Whether the overlying fine homogeneous gravel in which the stumps were buried is of Jamesburg date and of fluvial origin, or is of more recent date and possibly of wind-blown origin, and even within historical times, we leave for future determination.

Bone of a Dinosaur,

An Immense Reptile, Associated With Ammonites and Other Molluscan Fossils in Cretaceous (Matawan) Clay Marls, at Merchantville, N. J.

Elevation of surface at the locality, 76 feet.

The Pennsylvania Railroad Company put down a test boring at Merchantville, at the crossing of the Moorestown pike over their branch from Delair to Haddonfield. The strata are as follows:

Soil and loam	3	feet,	= 3	feet.
Light-colored clay	3	"	= 6	"
Yellowish-brown clay	6	"	= 12	"
Brown and yellow-mottled clay	6	"	= 18	"
Black clay marl	24	" +	= 42	" +

This boring was made preparatory to the making of a cut and the building of bridge abutments to permit the turnpike to cross the railroad above grade. On subsequently making the excavation there were found in the black clay marl of the above record, at the depth of 23 feet from the surface, or at an elevation above tide as stated by the company's engineer, of 53 feet, casts of ammonites and other molluscan fossils, the specific forms of which are the same as those occurring at Lenola, and which were noted in connection with the record of a well at Maple Shade, in the annual report for the year 1893. The following are the forms obtained here:

CEPHALOPODA.

Ammonites (Placenticeras) placenta, DeKay.
Ammonites delawarensis, Morton.
Nautilus dekayi, Morton.
Scaphites hippocrepis, DeKay.
Baculites ovatus, Say.

LAMELLIBRANCHIATA.

Axinea mortoni, Conrad.
Callista delawarensis, Gabb.
Cardium (Fragum) tenuistriatum, Whitfield.
Dianchora echinata, Morton.
Idonearca antrosa, Morton.
Martesia cretacea, Morton.
Neithea quinquecostata, Conrad.

Panopea decisa, Conrad.
Pholadomya occidentalis, Morton.
Plicatula urticosa, Morton.
Teredo tibialis, Morton.

GASTROPODA.

Avellana ——— ——— sp?
Lunatia halli, Gabb.
Pyropsis erraticus, Whitfield.
Turritella vertebroides, Morton.

DINOSAUR REMAINS.

A few feet above the molluscan horizon just noticed, there was obtained from the iron rusty, brown and mottled yellow clay of the above record one of the bones of the foot of an immense Dinosaur. Plate XV shows photographic views of the four sides of this bone, one-half the natural size, and also a view, natural size, and another slightly larger than nature of a cross-fracture of the shaft near the lower joint. The cancellated structure characteristic of bone tissue is well shown on the fractured surfaces. The bone is fifteen inches long, and near the middle of the shaft is four inches wide and two and one-half inches thick. On submitting the specimen to Prof. E. D. Cope, he pronounced it the middle metatarsal of the right hind limb of an animal of the family of Dinosaurian reptiles known as the Hadrosaurs. Without other portions of the skeleton he could not be certain as to the species, but said it was probably *Ornithotarsus immanis*, as named by him in 1869 from some bones found by the Rev. Samuel Lockwood in the clays on the shore of Raritan bay.

In the Museum of the Academy of Natural Science of Philadelphia there is a restored skeleton of another species of an Hadrosaurian Dinosaur (Hadrosaurus Foulkii, Cope), obtained from a higher stratum of the clay marls near Haddonfield, N. J., and but a few miles eastward from this locality. The corresponding bone in the Haddonfield specimen is but ten inches long, or two-thirds the size of the bone now being noticed. This indicates probably a much larger animal.

There are both carnivorous and herbivorous Dinosaurs; this one was probably herbivorous. These animals were dominant in Triassic, Jurassic and Cretaceous times. Many of them, and especially the Hadrosaur family, had comparatively short fore limbs, long hind limbs, and a long tail. The fore limbs had five digits, and the hind

ones only three. They walked on their hind limbs, and made immense three-toed impressions in the sands of their day, which have been especially well preserved in the Newark or Triassic red sandstones of the Connecticut valley, and were long erroneously supposed to be the tracks of large birds. The limb to which the bone at Merchantville belonged was probably about ten feet long.

View from the Base.

View toward the Base.

Silicified Tree Trunk, Lindenwold, N. J.

Silicified Tree-trunk at Lindenwold, N. J.

Length, 26 feet.
Diameter at the base, 7 feet 6 inches; diameter 12 feet higher, 5 feet.

The record of a well-boring on the 100-foot hill west of Lindenwold station, shows that beneath the surface gravels and sands, which are of a lightish-yellow color, there occurs a bed of deep orange-colored sand, the top of which is reached at about the depth of 25 feet. This sand bed, with the same characteristic color, is found beneath a thin layer of cultivated soil in a field about one-third of a mile northeast of the well, on ground twenty to forty feet lower and between the 80 and 60 foot contour lines shown on the topographical map of that region.

From this orange-colored sand, at a point in this field on the 70-foot contour line and on the south side of the valley occupied by the southernmost of the two main streams supplying Kirkwood pond, the farmer has been annually plowing up fragments of orange-colored silicified wood, which he has left strewn upon the surface so as to cover a space some twenty feet or more in diameter. Suspecting these indicated the remains of a fossilized stump, the writer, accompanied by three friends, visited the spot and had an excavation made revealing a prostrate tree-trunk, of which we present on plate XVI, reproductions from photographs taken by George Vaux, Jr., showing two views as it lay in the ground, one looking upward from the base and the other downward toward the base. Its width at the base is shown by two staves placed on the opposite sides, to the right and to the left of the sitting figure. It measured about seven feet six inches across at the base, which had been much broken by the plough. The width seven feet higher was six feet three inches, and five feet still higher five feet two inches. Beyond this the central part of the trunk was missing, but the outer portions continued as two parallel arms, in line with the lower part of the trunk, for about the same additional distance. The total length as carefully measured, was twenty-six feet. The tree lay pointing inward upon the side of a slope facing eastward. The base was even with the surface, but the upper end was buried about two and a half feet. The silicification is most perfect. The rings of annual growth are plainly shown. They numbered twenty in one fragment with a thickness of one inch, and fifty-two in another with a thickness of two

inches, while in another fragment, one and a half inches thick, seven rings were shown on one side within the space of one half an inch, and eight rings immediately adjoining on the other side within the space of one inch. The seven thinner rings were each of about the same average thickness. Each of the eight large ones were also of about an equal average thickness. Judging from the curvature of the rings, the thicker ones were on the outer side of the specimen. A few fragments were obtained in which the individual rings were of still greater thickness.

From the figures given above, an average of seventeen annual rings of growth per inch may be estimated. Six feet may also be taken as the average diameter and three feet as the radius of that portion of the trunk from which the fragments counted were taken. By calculation, we have 600 years as the approximate age of the tree when it fell. Fragments split lengthwise, as also those broken directly across, show beautifully the structure of wood. This is especially well seen by the use of an ordinary single magnifying glass or hand-lens.

A thin transparent radial section was ground and mounted in glycerine for microscopical examination by F. J. Keeley, a member of the Academy of Natural Sciences, of Philadelphia. The upper figure on plate XVII shows a photomicrograph of this section, magnified forty diameters by the use of a low power objective. Under a one-sixth objective, with careful illumination, a double row of bordered pits is seen on each of the tubes shown in the microphotograph, and which run lengthwise of the tree. The bordered pits are directly opposite each other—that is, they do not alternate. Occasionally, however, but one such pit is seen, which is then centrally located. On the lower half of plate XVII there is a drawing, about 250 diameters greater than nature, which shows three cell-walls, the middle one of which illustrates this exceptional structure. The bordered pits identify the tree as a conifer.

Similar thin sections, both transverse radial and tangential, have been prepared by the writer, mounted in Canada balsam. The transverse sections show a beautiful open cellular structure, very suggestive of the coniferous woods, but the writer's radial sections fail to show the bordered pits. It is thought, however, that these have been obliterated by the crystallizing process, which has been so complete in the specimens prepared that beautiful flat, six-sided crystals of quartz are seen crowded together throughout the whole woody structure.

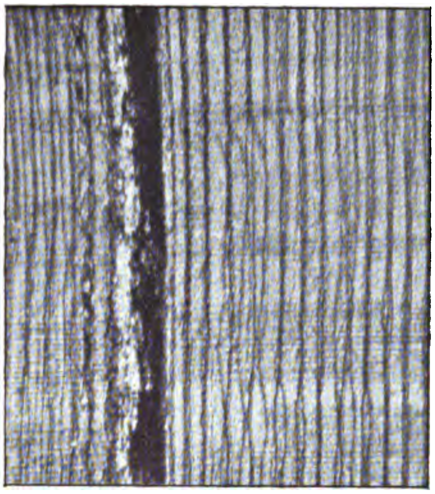


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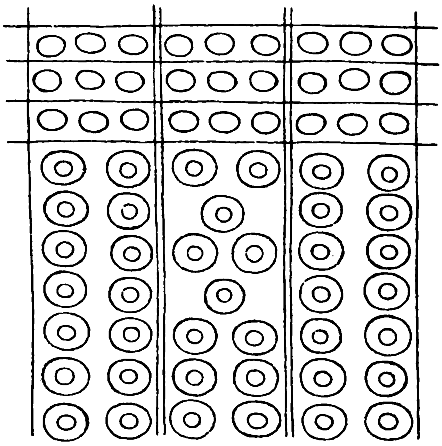
Photo-Micrograph of Radial Section, Lindenwold Silicified Tree Trunk, showing Cell Walls and Medullary (Cross) Rays.
The Dark Space Marks the Division between Two Annual Rings of Growth.



× 250.

Sketch of Three Cell Walls of Section Above, Still More Highly Magnified, showing Pits on Medullary (Cross) Rays and a Double Row of Tracheids or Bordered Pits on (Vertical) Cell Walls.
The Middle Cell Wall shows Two Exceptional Breaks in the Double-Row Arrangement of the Bordered Pits.

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With the polariscope and a selenite plate a magnificent display of variegated colors is developed, a phenomenon characteristic of crystalline, but not of amorphous quartz.

Possibly, however, the failure of the bordered pits to appear in the writer's sections may be partly due to the mounting medium, since F. J. Keeley tried his section first in balsam and again in monobromide of naphthaline without being able to see the pits.

The orange-yellow sand bed in which this trunk was buried, and the gravels of a lighter yellow color that overlie it at the locality of the Lindenwold well, near by, are known to have at least a wide local distribution, since the same succession of beds is shown in well-borings at Gibbsboro, two miles northeast; at Laurel Springs, nearly one mile southwest; at Lucaston, one mile southeast; and in the 160-foot hill, two and a half miles also southeast. The latter locality is one mile east of Clementon. It is probable however, indeed it is almost certain, that these beds occupy a much more extensive area than is here indicated.

Beacon Hill Molluscan Fossils, Fulgur and Venus, South of Millville, N. J.

The molluscan fossil casts shown on Plate XVIII are from the lower portion of Charles Key's glass-sand bank on the west side of Maurice river, about two miles below Millville. The glass-sand forms the lower two-thirds of an 86-foot hill and belongs to the Beacon Hill formation of Prof. R. D. Salisbury; the capping of the hill over the sand being a medium coarse gravel, the Pensauken formation of the same authority. In the annual report for 1894 Prof. Salisbury says that the Beacon Hill formation "is known to contain fossils at a point near Millville and at another near Mullica Hill." It may be that the Millville locality referred to is the same as that from which the fossils now figured were obtained. The glass-sand is mined at this locality upon the southern slope of the hill, one pit being in the upper portion of the bed west of the road leading southward from Millville, and another east of the road and in the lower portion of the bed which here forms the bluff, facing the river. The horizon containing the fossils is in this bluff. They are occasionally thrown out by the workmen, though they are not at all plentiful.

The specimens figured, plate XVIII, were kindly presented to the writer by Charles Key. It will be seen they represent two species, one a bivalve, probably a Venus, and undoubtedly a clam, perhaps much like the edible clam of to-day, *Venus mercenaria;* the other, a univalve shell, probably much like the conch, with protuberances on the whorls, which can be picked up on the New Jersey beach to-day, and technically known as *Fulgur carica.*

As fossils they are poor casts, and yet very good for the locality. So far as we know they are the first mollusks figured from the Beacon Hill formation. All of the casts are geodes, and consist of an outer thin shell of cemented sand, the interior of which is filled with a very fine, almost impalpable, powder of iron oxide (iron rust). The dark space on the front of the middle Fulgur on the plate shows an opening artificially broken into the interior cavity. The casts are slightly flattened. The figures are natural size. Three specimens have been deposited in the Museum of the Survey, at Trenton, and three others in the Academy of Natural Sciences of Philadelphia.

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PART V.

Notes of the Flood of February 6th, 1896, in Northern New Jersey.

BY

C. C. VERMEULE.

Notes of the Flood of February 6th, 1896, in Northern New Jersey.

BY C. C. VERMEULE.

On February 6th of the present year violent and disastrous floods occurred on all of the streams of the northern part of the State. In the last annual report we discussed at some length the effect of forests upon stream-flow, reaching the conclusion that the presence of forest could exercise no marked control over the rate of discharge of extremely high floods. The Report on Water-Supply, of 1894, also gave a very full discussion of the floods on our several streams. In the notes of floods on the Raritan river in that report it was pointed out that there had been three very high ones during the century, namely, November 24th, 1810; July 17th, 1865, and September 24th, 1882. The great flood of this year followed so closely upon these studies that it presented an unusually favorable opportunity for further examination and investigation of the subject, an opportunity which occurs generally but once in a generation. Field examinations and copious notes were consequently made immediately, the results of which it is now our purpose to present.

The conditions of frozen ground, a considerable amount of accumulated snow, and a sudden heavy, warm rain are such as might be expected to cause extremely heavy floods. All of such conditions were present at this time, yet, strange to say, the three previous heavy floods of the century, to which we have referred, occurred during the summer and autumn months, which shows that there are other causes which produce heavy freshets. The destructiveness of the flood is always determined by its rate of maximum discharge, rather than by the total volume of water run off from the catchment. This flood of 1896 was peculiar in its remarkably sudden rise and high maximum rate of discharge. On most of the streams this rate exceeded that of 1882, which we have considered heretofore to be as high as any previous flood of the century.

The Raritan river reached its maximum in 15 hours against 38 hours in 1882, and the maximum rate of discharge was 15 per cent. greater than that of 1882, whereas the total amount of water delivered in a period of 64 hours from the rise was 16 per cent. less than in 1882. On the Passaic, the maximum was reached in 44 hours against 66 hours in 1882, but the rate of discharge was 8 per cent. and the volume 14 per cent. less than in 1882. But on the Passaic branches we observe the same quick rise, and a maximum rate exceeding that of 1882 by about 10 per cent. on the Wanaque, 25 per cent. on the Pequannock and 12 per cent. on the Rockaway. The Whippany also exceeded the highest previous flood, but the Ramapo, being blocked with ice, showed a rate of discharge 20 per cent. less than in 1882. The reason for this extremely quick and violent rise is found in the meteorological conditions which prevailed. On the 6th there was generally from 6 to 8 inches of snow lying upon the ground over the Passaic and Raritan catchments. It grew suddenly warm and began to rain in the forenoon, the temperature reaching a maximum of about 52 degrees on the Highlands, and 55 degrees on the Red Sandstone plain. The rainfall amounted to about 3.7 inches in 24 hours. Just before noon on the 6th, the snow began to melt and went off with great rapidity, adding an average of about .6 of an inch, so that a total of 4.3 inches depth of water over the entire watershed resulted from the combined rainfall and melting snow. So much of this as could not be absorbed by the ground or held in the lakes, which were low at the time, rushed at once to the streams and had to be discharged. Our examinations show that from 2.5 to 3.5 inches went off in flood discharge, and the remainder was almost entirely absorbed by the ground. In the case of the Passaic, about one-quarter of an inch was held in the lakes and ponds. The amount of evaporation which could have taken place during the short period of about three days in which the flood was discharged, could not possibly have exceeded .1 of an inch, and it becomes plain from these figures that it is wrong to assume that under such conditions as these frozen earth cannot absorb a considerable amount of rainfall. Absorption is undoubtedly somewhat retarded by such frozen conditions, and what determines the volume of flood discharge is the amount of rainfall or melted snow in excess of the amount which the earth can absorb. In the case of the flood of September, 1882, the rainfall amounted to over 10.5 inches, of which about 3.5 inches was discharged in flood, and the difference of 7 inches

was practically all taken up at that time by the ground, a prolonged dry period having preceded the flood. If at any time such a rainfall should occur when the ground was already full of water, it is appalling to think of what the result would be upon such a stream as the Raritan.

A study in detail of the action of such great floods as that of last February on such streams as the Passaic and Raritan is the best possible way to arrive at a clear understanding of the action of streams in floods and all the conditions which govern the rate of discharge and its volume. These studies are well calculated to throw the light of truth on the effect of such forests as prevail in New Jersey upon flood-discharge, for the reason that we have widely varying portions of forest area on the several branches considered. These studies in relation to forestry have been prosecuted in a spirit entirely friendly to the cause of forest preservation and improvement. It has appeared to the writer that, while the real effect of forests upon the regulation of stream-flow is of the highest economic benefit, some of the reasons advanced for the preservation of forests in connection with stream-flow are unfounded. The danger to the cause of forestry has appeared to be that before long investigation must prove conclusively that the reasons thus advanced had no foundation in fact. Should this point be reached before the real beneficial effect of forests has been clearly pointed out, the result may be a reaction most injurious to the whole cause of forestry. The investigations made by the survey in this connection have been entirely in the interest of truth, which is the only safe basis on which an argument for the preservation of our forests can rest. In the last annual report we attempted to point out what the real beneficial effects of forests upon streams were, and as our studies of the present flood have caused no important modification of the views then expressed, we may recapitulate that they were to the effect that forests do not diminish to an important extent the height or the extreme high floods, but do materially diminish the number of floods; also, that even heavily forested streams will occasionally be subject to very low stages in dry seasons; but, nevertheless, the dry periods on forested streams will be much shorter and less frequent, and that such streams, because of the general equalizing effect of forest, will be far more useful for purposes of water-supply or water-power than streams the catchments of which are deforested. It was also pointed out that streams with forested catchments would be less

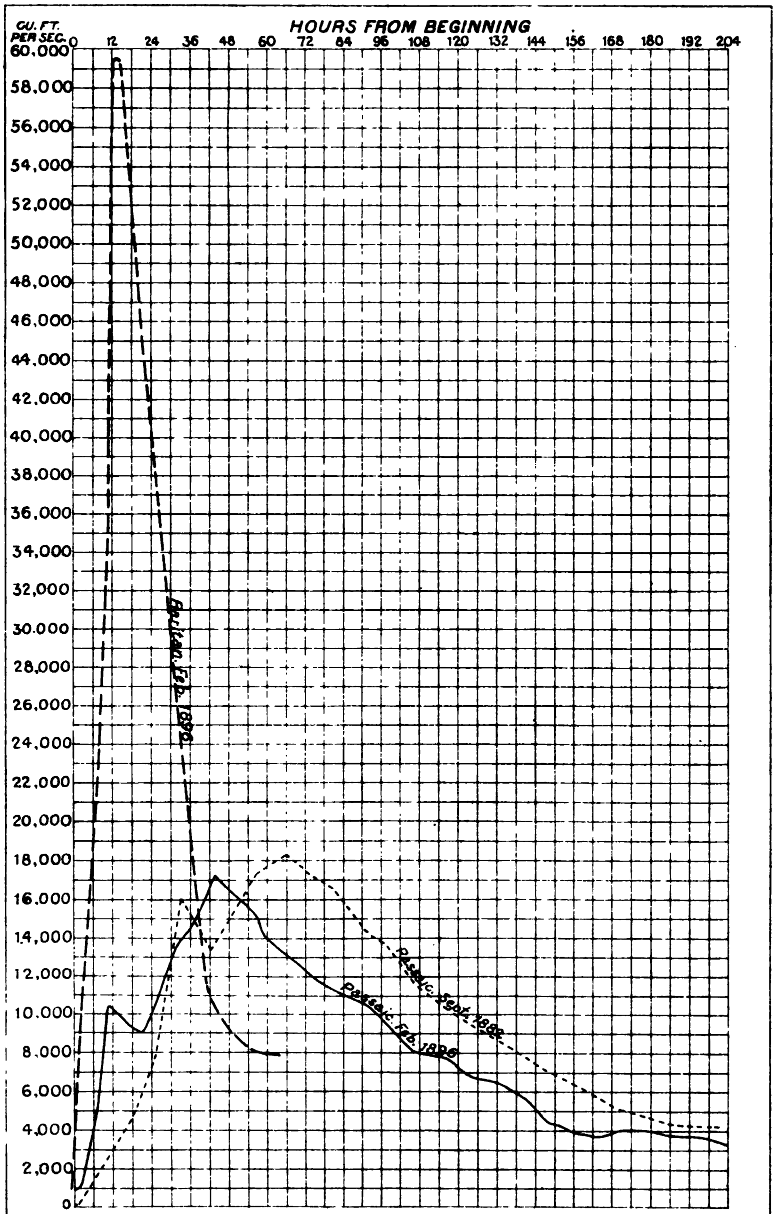
subject to roiliness, and the soil of their catchments would suffer less from wash.

Returning to the causes of the flood of February 6th, a careful examination of the records of the New Jersey State Weather Service shows that the conditions were as given in the following table:

RAIN AND SNOW IN INCHES.

Passaic Water-shed.	Rain, Feb. 6th and 7th.	Snow.	Total.
Highland portion	4.15	.70	4.85
Red sandstone portion	3.30	.60	3.90
Whole catchment	3.72	.65	4.37
Raritan Water-shed.			
Highland portion	4.10	.70	4.80
Central Valley	3.55	.60	4.15
Upper Millstone	3.55	.40	3.95
Whole catchment	3.66	.60	4.26

The rain given as falling on the 6th and 7th practically all fell in 24 hours, beginning with the morning of the 6th. The column headed "Snow" is snow reduced to water, by the common rule, taking one-tenth of the depth of snow on the ground. This probably underrates the amount of the water from the melting of the snow and ice. This is added to the rainfall to give the total amount of water upon the catchment of the streams. The snow apparently began to melt somewhat earlier on the Raritan than on the Passaic catchments, and earlier in each case on the red sandstone portion than on the Highland portion of the catchment. Generally it began to melt between 6 and 9 A. M., and between 9 and 11 had become saturated with water and went off to the streams with great rapidity. The temperature records show that it was three or four degrees warmer on the red sandstone plain than it was on the Highlands on the 6th, and on the Millstone catchment it was fully eight degrees warmer than on the Highlands. It apparently averaged fully four degrees warmer on the Raritan than on the Passaic catchment. It will be seen from the table that the rainfall in the Highlands was heavier than on the red sandstone, and that the combined rain and snow amounted to upwards of 4.8 inches on the Highlands, against about 3.9 inches on the red sandstone plain. Carefully equating the results, it is evident that there was no material difference in the total supply of water per square mile from rain and snow combined on the Passaic and Raritan catchments.



COMPARATIVE DIAGRAM FOR PASSAIC FLOODS OF 1896 AND 1882.

Passaic Catchment.—The rise began on the Passaic, at Dundee, at 10 A. M., on the 6th, and the river began to rise very rapidly about 1 P. M. At 9 P. M. it had reached a discharge of 10,442 cubic feet per second. It then began to fall off and continued falling until about 7 A. M. of the 7th, when it again began to rise rapidly, reaching a maximum of 17,217 cubic feet per second about 6:15 A. M. of the 8th, after which it fell off uniformly, the entire period of flood being eight days, which is the usual duration of floods on the Passaic. The accompanying diagram, Fig. 1, shows the movement of the flood at Dundee, and Fig. 2 compares it with a similar diagram for the flood of September, 1882. In 1882 the maximum rate of discharge at Dundee was 18,265 cubic feet per second, which was reached sixty-six hours after the beginning of the rise. The area of the catchment at Dundee is 822.7 square miles. In the Report on Water-Supply, page 153, a full history is given of the flood of 1882, and a table of all the floods on the river from 1877 to 1893, a period of seventeen years. The flood of 1882 also showed an early rise followed by a falling-off of the stream, and in both cases this is found to be due to the quick rise of the Pompton. A complete record of the flood of this year, including several readings each day at Dundee dam, was obtained by the courtesy of the Dundee Water Power and Land Company.

At Little Falls a record was also obtained which shows clearly that the movement of the river there agreed in time quite closely with Dundee, and that the discharge was closely proportional to the discharge at Dundee, the drainage area above Little Falls being 773 square miles. At 7 A. M. on the 8th the river was discharging over Little Falls dam at the rate of 16,745 cubic feet per second. The Dundee record being, on the whole, more complete and satisfactory, it has been adopted in preference to the Little Falls record in our studies of the flood. The diagram for Dundee will answer equally well for Little Falls if 6 per cent. is deducted from the amount to find the discharge at any given period. The river is practically within its banks when it reaches a discharge of 4,000 cubic feet per second.

On Pompton river, at the head of the Pompton feeder of the Morris canal and at the junction of the Ramapo, the rise began at 10 A. M. on the 6th, and at 11 P.M. the highest point was reached. On the morning of the 7th the stream had fallen one foot. Mr. Graham, who lives nearby, says the river at this point was higher than it has

been in thirty years. This is just below the junction of the Ramapo, Wanaque and Pequannock.

At the dam on the Ramapo river, at Pompton, the water began to rise about 9 A. M., continuing steadily until 12 P. M., then more slowly until 9 A. M. of the 7th, when it reached its maximum of 8,731 cubic feet per second. This was considerably less than the maximum of 1882, which amounted to 10,540 cubic feet per second. Inquiry at Oakland shows that the river reached its highest there at 10 P. M. of the 6th. There was an ice gorge above the Pompton dam which held the water back at the highest, and made the discharge of the river more gradual. It remained at nearly the highest point for 9 hours, and there is little doubt that this is the cause of a somewhat lower discharge at the maximum than we should have had otherwise. The following table shows how the river discharged over Pompton dam:

Date.	Hour.	Discharge. Cubic feet per second.
5th	9 A. M	312
6th	9 A. M	890
6th	12 P. M	7,609
7th	2 A. M	8,100
7th	9 A. M	8,731
7th	5 P. M	4,619
8th	9 A. M	3,310
8th	5 P. M	2,510
9th	9 A. M	1,200

We find from this that in a period of 72 hours the Ramapo discharged 1,166 million cubic feet, or 3.13 inches in depth upon its catchment. The area of the catchment is 160 square miles.

At Ramapo, New York, the Ramapo river has a catchment of 86 square miles. At this point the rise began at about the same time on the morning of the 6th, and the river reached its maximum at 11 P. M., when it discharged 4,800 cubic feet per second. At 10 A. M. on the 7th the discharge was 3,500 cubic feet per second, and the river fell back to a normal discharge at 10 A. M. on the 9th, about 72 hours after the beginning of the rise. The total volume discharged amounted to 3.01 inches upon the catchment, about half of which was discharged in the first 24 hours.

Wanaque river has a catchment of 101 square miles above the dam at Pompton. The rise began at 9 A. M. of the 6th, and at 9 P. M. the stream reached it maximum discharge of 7,203 cubic feet

per second. It then fell off quite steadily, the flood being almost over in 36 hours. In a period of 72 hours the discharge amounted to 510 million cubic feet, or about 2.18 inches on the catchment. About one-third of the catchment is controlled, however, by Greenwood and Sterling lakes, and consequently had its flood-flow held back, which would bring the total discharge nearly proportional to that for the Ramapo. This gives the maximum discharge at a high rate—nearly 100 cubic feet per second per square mile.

The Pequannock has a catchment area of 85 square miles. The rise commenced about 10 A. M. Thursday, and at 4:30 P. M. the stream reached its maximum of 5,500 cubic feet per second and did not fall below 3,600 cubic feet per second until 8 P. M. The flood was over within 24 hours. The storage reservoirs of the East Jersey Water Company caught the flow of 37 square miles, so that the above maximum is that of 48 square miles of catchment.

Mr. Clemens Herschel, engineer of the East Jersey Water Company, kindly furnishes the following discharge, or natural flow of river at Macopin intake during the flood: February 5th, 47,600,000 gallons; February 6th, 1,703,300,000 gallons; February 7th, 1,674,-800,000 gallons; February 8th, 398,700,000 gallons; February 9th, 293,700,000 gallons. This is from 63 square miles of catchment.

On the Rockaway river at Boonton the rise began about 10 A. M. of the 6th, and at 6 P. M. the depth on the dam had increased 24 inches. At 7 P. M. there was $3\frac{1}{2}$ feet of water on the dam. At 2 A. M. of the 7th the river had reached its maximum discharge of 5,445 cubic feet per second. In September, 1882, the maximum discharge was 4,800 cubic feet per second, so that the present freshet was much higher. It was the highest known flood at this point, and it did considerable damage below the falls, washing away the high railroad trestle. The following table shows the rate of discharge during the flood, which was over in less than 48 hours. The catchment area is 118 square miles:

Date.	Hour.	Discharge, cubic feet per second.
6th	12 noon	165
6th	7 P. M.	3,390
7th	2 A. M.	5,445
7th	3 A. M.	5,400
7th	5 A. M.	5,060
7th	12 noon	3,830
7th	5:30 P. M.	3,000
8th	9 A. M.	800

The total volume discharged during a period convering 72 hours from the rise was 685 million cubic feet, or about 2.50 inches upon the catchment.

On the Whippany the flood was very heavy, and the dam at Morristown went out, somewhat increasing the rapidity of the rise. At Whippany the rise began at about 10 A. M. of the 6th, and the maximum was reached at 8:03 P. M., amounting to about 3,200 cubic feet per second on 38 square miles. This was the highest ever known. About 5:30 P. M. the water rose about 7 inches in 15 minutes, then fell away slightly, and afterward rose again steadily to the maximum. This first rise was probably the water from the lake at Morristown. In 21 hours from the beginning the river was back to about its normal condition. The total volume discharged amounted to 153 million cubic feet.

At Chatham the rise in the Upper Passaic began about 9 A. M., and was very rapid. The maximum was reached about 3:30 P. M., and the river did not fall much until the afternoon of the 8th.

At Cook's bridge the rise began at about 10 A. M., and continued for about 24 hours, after which it remained nearly stationary from 12 to 15 hours. The water was about one foot lower than in 1882. The rise amounted to about 5½ feet.

At Pine Brook the water began to rise about 10:30 A. M., of the 6th, this water being local from the rain and melting snows in the immediate neighborhood. The waters from above did not get down until night. By about 5 P. M. the rise amounted to from 12 to 16 inches, and the water continued rising until the afternoon of the 7th, then remained stationary about 24 hours. At 3 P. M. of the 8th it had only fallen a quarter of an inch, and at 5 P. M from one-half to three-quarters of an inch. The rise amounted to a little over 5 feet. The morning of the 9th the fall amounted to 2 inches, and by the evening of the same day 6 inches. The morning of the 10th it was down 1 foot. The Rockaway, at Pine Brook, began to fall before the Passaic had reached its highest point.

The following table shows how the maximum discharge at various points compared with the maximum in September, 1882. We repeat that it is our belief that the Ramapo, if it had not been restrained by an ice-gorge, would have reached a higher rate of discharge, probably as high as in 1882. Allowing for this, it is observable that on the branches the maximum was reached much earlier during the present

flood, and was at a considerably higher rate than in 1882. The Ramapo, we should also repeat, reached its maximum at Oakland, just above Pompton, about 12 hours after the beginning, and this would have been the actual time at Pompton if unrestrained. The maximum rate at Little Falls and Dundee is controlled by entirely different conditions from those which determine the maximum rate on the branches. The volume of the flood and the extent to which it fills up the meadows above Two Bridges, determines the rate of discharge at those points, and we have already remarked that this volume was considerably less than in 1882. Both of these points, however, show the suddenness of the rise.

RATES OF FLOOD DISCHARGE.

	Catchment—Square miles.	September 22, 1882.		February 6, 1896.	
		Hours, beginning, to maximum.	Greatest discharge, cubic feet, per second.	Hours, beginning, to maximum.	Greatest discharge, cubic feet, per second.
Passaic, Dundee	822	66	18,265	44	17,217
" Little Falls	773	66	19,000	44	16,745
Ramapo	160	24	10,540	24	8,731
Wanaque	101	24	6,666	11	7.203
Pequannock	85	20	4,460	7	5,500
Rockaway	118	36	4,800	16	5,445
Whippany	38	...	....	10	3,200

The maximum rate of discharge may be greatly modified by local conditions, natural or artificial obstructions and other minor causes. It is always influenced largely by topographical conditions also, mainly the extent of the flood plain and the rate of fall of the valley, together with the arrangement of the branches. A stream made up of several branches of nearly equal length converging within a short distance along the valley will show a much higher rate of discharge than where the main stream is long and has many short tributaries distributed quite evenly along its length. In the latter case the flood will remain near its highest a considerable length of time. A much better indication of the rapidity with which a watershed yields up the water falling on it is had by studying the volume of water discharged during a certain number of hours from the beginning of the rise.

From the data obtained by us at the several gauging points, we have made up the diagram, Plate 19. This shows the rate of discharge of

the Passaic and its branches from the beginning to the end of the flood. The diagram for the Passaic is for the discharge at Dundee. The curve for Little Falls would be very similar, as we have already explained. The diagrams for the Ramapo, Wanaque, Pequannock and Rockaway are also from observation. The first three unite at Pompton to form the Pompton river, and our gauging points being in each case a short distance above their confluence, we are enabled to build up from the three a pretty accurate diagram for the discharge of the Pompton itself. This diagram shows the rate of discharge for that stream at Pompton Plains where its catchment area is 350 square miles, and before it has had an opportunity to spread over the broad extent of meadows below. It will be noted that our estimate of maximum discharge for the Pompton is greater than for the whole Passaic. There can be no reasonable doubt as to the accuracy of this conclusion. Had not the Ramapo maximum been suppressed by the ice-gorge which we have referred to, the Pompton maximum would probably have been nearly one thousand cubic feet per second greater. As it is, we estimate it at 18,500 cubic feet per second.

It will be noted that the Pompton catchment area is somewhat less than half the total area above Little Falls. The remainder is made up of the Whippany, Rockaway and Upper Passaic. These treams all fall into a wide expanse of flat meadows long before reaching a junction with the Pompton at Two Bridges. They do not, therefore, come together so as to form one stream like the Pompton, but their waters are widely dispersed over the flat. Taking the diagrams for the Rockaway, however, and the facts ascertained as to th Whippany and Upper Passaic discharges, we can draw a plain inference that if the waters had been confined to the stream channels instead of spreading over the meadows they would have delivered at Two Bridges in very much the same way that the Pompton delivered its waters. The maximum would probably have been reached a very little later, and the Passaic at Little Falls would have reached its maximum discharge at nearly the same time. This maximum could not well have been less, under such conditions, than about 38,000 cubic feet per second, instead of the 16,745 cubic feet per second actually recorded. What actually happened was that the water was poured into the broad flats in the Central Valley, including a total of some 30,000 acres, at about the rate which we have indicated. The rise of the Passaic at Little Falls was governed by the filling up of these

flats until a sufficient height was reached at Two Bridges to enable the channel thence to Little Falls to reach the recorded maximum discharge. This was not accomplished until 30 hours after the time of maximum discharge of the branches into the central valley. The difference between the large volume discharged into the central valley and the much smaller amount passing Little Falls, accumulated on the flats, and was not entirely discharged until the 8th day after the beginning of the rise. The following table shows the total volume of water discharged into the valley at the end of the first, second and third days of flood and the corresponding amounts discharged from the valley at Little Falls, together with the accumulation of water in the valley. The amounts are determined by gauging, except for the last three catchment areas, which had to be estimated. No serious error is believed to exist from this cause.

FLOOD-DISCHARGE INTO CENTRAL PASSAIC VALLEY.

Beginning February 6th, 1896, at 10 A. M.

Catchment.	Area, square miles.	TOTAL DISCHARGE IN MILLION CUBIC FEET.		
		In 24 hours.	In 48 hours.	In 72 hours.
Ramapo	160	498	975	1,166
Wanaque	101	337	424	510
Pequannock	85	299	337	391
Rockaway	118	333	570	685
Whippany	25	126	140	153
Lower Pompton	34	112	170	195
Upper Passaic	100	330	500	570
Central Valley	150	495	750	855
Above Little Falls	773	2,530	3,866	4,525
Discharged at Little Falls	773	650	2,023	3,094
Accumulated in valley	....	1,880	1,843	1,331

It will be noted that the greatest accumulation of water on the flats was at the end of 24 hours, there being no substantial decrease in the accumulation up to the end of the second day.

The diagrams of discharge over Dundee dam for the floods of February 6th, 1896, and September 22d, 1882, are shown in Plate 20, the time being reckoned from the beginning of the rise. This shows plainly the smaller volume of the flood of the present year, and also its rapid rise. Both diagrams show the preliminary maximum followed by a falling of the river, and in each case this occurred

just 33 hours before the river reached its highest point. It agrees in time with the maximum of the Pompton, and is undoubtedly due to the rush of water from that stream, together with the water from the lower portion of the catchment between Little Falls and Dundee. That it does not rise much higher is due to the fact that a large part of the water from the Pompton goes to fill up its own flats above Mountain View, and also the Great Piece meadow at Two Bridges. Its waters reached Two Bridges considerably before those of the Rockaway, Whippany and Upper Passaic were able to come down across the flats. A strong upward current is noticed at Two Bridges during every high flood at the time when the Pompton is filling up Big Piece meadows with water. In 72 hours the discharge at Dundee amounted to 3,292 million cubic feet, or 1.72 inches upon the catchment, while during the entire period of 8 days it was 6,083,000,000 cubic feet, or 3.18 inches upon the catchment. The following table shows how the flood of February 6th compared both in maximum rate and volume with the three greatest floods since 1876.

GREATEST FLOODS ON THE PASSAIC AT DUNDEE SINCE 1876.

Area of watershed, 822.7 square miles.

Date of maximum discharge.	Maximum flow, cubic feet per second.	Time from beginning of rise to: Maximum, hours.	End, days.	Total flow in million cubic feet.	Inches on watershed.
September 25th, 1882......	18,265	66	8	7,101	3.71
February 8th, 1896.........	17,217	44	8	6,083	3.18
December 12th, 1878.......	16,592	60	8	6,878	3.47
February 14th, 1886.......	12,452	60	8	5,729	3.00

Raritan Catchment.—On the Raritan the flood of February 6th was discharged with great violence. It showed even an exaggeration of its usual contrast to the discharge of the Passaic at Dundee. This was no doubt partly due to the earlier melting of the snow. The general results of our inquiries are to the effect that the snow melted first of all on the Upper Millstone, but all over the Red Sandstone portion of the watershed it was running off at 7 A. M., whereas in the Highlands along the North Branch it began to go between 9 and 10 A. M., and through the German valley about 9 A. M. We can safely infer that on the higher portions of the Highlands it was a little later still. It probably averaged nearly three hours earlier on the Raritan than on the Passaic catchment.

At the Delaware and Raritan canal dam, below Bound Brook, the river began to rise at 8 A. M. of Thursday, and during the afternoon rose very rapidly. It reached a height of 15.2 feet above the crest of the dam, about one foot higher than in 1882. The highest point was reached about midnight, and at 8 A. M. of the 7th it had fallen about two feet. At 8 A. M. of the 8th the river was within its banks. At Bound Brook the rise agreed in time with that at the dam below. Here, and up to the mouth of the Millstone the rise was first noticed about 9 A. M. and the river rose steadily all day. From 5 to 11 o'clock P. M. it was very rapid, amounting to four feet from 5 to 8 P. M., and nearly as much more by 11 P. M. It is said that near 5 P. M. the river rose ten inches in as many minutes. It was highest here about 11 P. M. Much damage was done in this vicinity. The highway bridge at Finderne was carried away, also the Philadelphia and Reading railroad bridge, and the banks of the railroad were washed out. The tracks of the Central Railroad of New Jersey and of the Lehigh Valley railroad were under for some distance, and traffic was seriously impeded on the Central and Reading railroads. The water was also deep in the lower streets of Bound Brook village, and a fire caused by the flood reaching some stored lime added largely to the damage done. Inquiry on the Millstone river indicates that that stream below Rocky Hill reached its maximum about 3 P. M., the maximum being clearly shown at Blackwell's Mills and Griggstown. The rise of the Raritan continued, however, until 11 P. M., backing the water so that it also rose at Weston, on the lower part of the Millstone, until 11 P. M. The flood on the Millstone itself was less severe than in 1882. At Blackwell's it is said to have been the highest at 4:30 P. M., and at 3:15 to 4:15 P. M. the river rose ten and one-half inches, going up much faster than usual. The flood was about seven feet higher than the ordinary level of the river, but four feet lower than the flood of 1882. The stream was about three days getting back to its normal flow.

At Griggstown the river reached its highest point at 2 P. M., when it was 8 feet above the usual level of the river, and the river did not reach its normal condition until the morning of the 9th. It was 5 feet 8 inches lower than the flood of 1882.

At Rocky Hill the river is said to have begun to rise at 4 A. M., and by 7 A. M. was up 18 inches. It did not reach the highest at this point until 9:30 P. M., and by 11 P. M. had fallen three inches,

and at 7:30 A. M. Friday was down 18 inches. During Friday it fell about one foot more, and by the morning of the 9th was within its banks. At 5 P. M. the river commenced rising rapidly, gaining four inches in half an hour. It was 7 feet 6 inches higher than the ordinary level, but 5 feet lower than the flood of 1882.

It is quite clearly indicated in the notes for Millstone river, that the red sandstone portion of the water-shed discharged its waters most rapidly. The entire catchment measures 286 square miles, of which 99 square miles is on the Cretaceous formation, very flat and gravelly. The remainder, being the lower portion of the water-shed, is steeper and quite bare of forest. The maximum noted at Blackwell's and Griggstown was undoubtedly due to the discharge from this red sandstone portion. The maximum at Rocky Hill was from the slower waters of the upper Millstone. This is the usual movement of waters on the Millstone, and gives rise to a lower maximum rate of discharge for the whole water-shed as compared with the rest of the Raritan branches. The remarkable difference noted of about 5 feet between the height of this flood and that of September, 1882, the total rise in February being only from 7 to 8 feet against from 12 to 14 feet in 1882, does not indicate such an extreme difference in the rate of discharge as would at first appear. It must have been partly due to the fact that the Millstone reached and passed its maximum several hours before the Raritan, and is also partly due to the gentle inclination of the trough-shaped valley of the Millstone, the fall amounting to only about 18 inches per mile. The valley being narrow and the floods closely confined, any addition to the rate of maximum discharge causes a rapid increase in height in order that the stream may acquire the velocity necessary to pass off the flood.

At Raritan, on the main river, the maximum was reached at 7 P. M., the beginning having been early in the morning. The river reached a height of 23 feet above its normal level, and it is said that between 4:30 and 5 P. M. it rose 13 inches in 15 minutes. From high-water marks it is said to have been 32 inches higher than the highest previous flood. The river was back to its normal condition in about 3 days. Much damage was done here. The bank of the water-power raceway was severely washed, and the fencing on the low lands was destroyed. Some of the mills also suffered a considerable amount of damage. At South Branch the rise began at 7:30 A. M. and after 8:30 it was rapid. From 10:45 A. M. to noon it amounted

to one foot; after noon it was more rapid, and was the highest from 4:30 to 5 P.M. It reached a height of 14 feet on the dam, and 20½ feet above the ordinary level below the dam. By 4:30 A. M. of the 7th it had fallen 5½ feet, and the river reached its normal condition in about 60 hours. From flood-marks in the mill this flood was 15½ inches higher than that of 1865, which was noted in the Report on Water-Supply as being one of the three heavy floods of the century on the main river. It may be observed here that these three floods of 1810, 1865 and 1882, together with the present flood of 1896, were remarkable in that they were general over a considerable extent of country, but it would appear that on some of the smaller water-sheds as high floods have occurred at more frequent intervals, thus the flood of 1850 is said to have been as high at South Branch as that of 1865. As we shall point out later, it cannot be assumed from height alone that the maximum rate of discharge of the present flood is greater than of any previous flood, because we must take into account the many artificial obstructions which have been introduced along the course of the stream, and which tend to retard the discharge and increase the height at many points.

At Neshanic the rise commenced about 9 o'clock Thursday, and the river came up very fast, reaching nearly the maximum at 2:30 P.M., but continuing to rise slowly until about 5 P.M., when it began to fall. The reason of the long high water here is stated to have been that the Neshanic discharged its flood first, the South Branch following later. This is but a partial reason, as the same thing was repeated all along the course of the South Branch, which is a long stream, having comparatively short branches scattered along its course. Such conditions always produce the effect of holding the river near its maximum a long time. From flood-marks in the mill at Neshanic it is found that this freshet is 1.85 feet higher than that of 1882, 2.21 feet higher than that of 1865, and 2.75 feet higher than that of 1850. It reached a height of twelve feet on the dam. The South Branch discharged an amount of water equivalent to 3.22 inches during the entire seventy-two hours of flood. About noon, on February 6th, the water is said to have risen two feet in twenty-five minutes. Our record of relative heights of previous floods at this point is not a correct indication of the relative rate of discharge, as there have been obstructions introduced on the stream.

At Black Point Bridge, at the mouth of the Neshanic river, the water rose fourteen feet above the ordinary level of the river.

At Three Bridges the rise began about 8 A.M., and the highest was reached at 5 P.M. At 7:30 P.M. the river had fallen one foot.

At Clinton the river began to rise about 7 A.M., continuing slowly until 11 A. M., after which it came up very fast, being most rapid from 12 to 1 P.M. The maximum was reached, it is said, at 8:30 P. M., there being a first maximum at 6 P.M. We are inclined to think that the second rise was due to some obstruction. After 9 P. M. the river fell steadily; it was four feet high on the dam. The water of Spruce Run usually comes down first; that from the South Branch about one hour later.

At Taylor's iron-works, High Bridge, it was noted that the river had risen considerably at 11 o'clock A. M. At 5:15 P. M. it reached the highest, 5 feet 6½ inches on the crest of the dam, and we find the rate of discharge at this time to have been 7,558 cubic feet per second, or 113 cubic feet per second per square mile, the catchment measuring about 67 square miles. The water remained stationary about three quarters of an hour, then began to fall. At 11 P. M. it had fallen three feet, and the stream reached its normal condition in about three days. The total volume of discharge in 72 hours was 484,000,000 cubic feet, or 3.12 inches on the water-shed, of which 1.13 inches was discharged in the first 12 hours, and 1.73 in 24 hours from the beginning. Through the German Valley above High Bridge the rise began about 9 A. M. It was highest at Califon at 5 P. M., at Middle Valley at 4, at German Valley at 5:30, and at Naughright at 2 P. M., remaining nearly stationary one hour. The river was within its banks the morning of the 7th. It is everywhere said to have been the highest on record. Most of the dams through the valley were injured more or less, and also some of the mill properties, while the road from Califon to High Bridge along the river was made impassable. There was a good deal of damage done also on the lower part of the South Branch, notably at Neshanic, where the store was flooded, the mill property damaged and the highway bridge carried away. Much fencing was destroyed, and the railroads were washed and traffic impeded.

We have noted a rate of 113 cubic feet per second per square mile at High Bridge from 67 square miles of water-shed. Computations made in two or three different ways all indicate that the discharge from the entire 276 square miles of catchment of the South Branch was at a rate very close to 100 cubic feet per second per square mile.

On the North Branch at Milltown, just above its confluence with the South Branch, the river began to rise about 7 A. M., rising slowly until 11 A. M., while during the next half hour the rise amounted to 22 inches. The highest point was reached at 5:30 P. M.; at 6 P. M. the river was falling. The rise was said to be faster than ever noticed before. The water reached a depth of 6½ feet on the dam, and 13 feet above the river below the dam.

At North Branch village the river was observed to be rising at 9 A. M., and was over its banks at noon. From 2 to 3 P. M. the rise amounted to 2 feet, and the highest point was reached about 5 P. M. The river appears to have continued near the maximum from 4:30 to 5:30 P. M. It reached a height of 13 feet above ordinary level of the river at the village bridge. Marks in the mill showed it to be 1.2 feet higher than the freshet of 1887, and 2.2 feet higher than the one of 1886. It was also said to have been the highest at this point since 1850, but the flood of that year was thought to be about the same height at points above on the stream where no artificial obstructions had been introduced meanwhile. The water came in several houses at this point, and much damage was done.

Chambers' or Dumont's brook is a small branch of the North Branch at North Branch station. An approximate estimate of the discharge of this brook gave a maximum rate of 140 cubic feet per second per square mile from 10.5 square miles of catchment.

At Bedminster the river was noticed to be rising at 10 A. M., and the flood reached a height of six and one-half feet above the ordinary level of the river. The maximum was reached between 3 and 4 o'clock, and the river soon began to fall. The evening of the 7th it had almost reached its normal condition.

At Hub Hollow, above Bedminster, the river was observed to be rising at 6:30 A. M., and it reached the highest at 1:45 P. M. At 3 P. M. it had fallen one foot, and at 5 P. M. four feet, the flood being practically over on the morning of the 7th. It was seven feet higher than the ordinary stage of the river. About noon the river is said to have risen 13 inches in fifteen minutes. It is claimed to have been 18 inches higher than ever known before.

At Roxiticus snow began to run off at 10:30 A. M., and from 12 to 12:30 the water rose 16 inches. It is said to have been higher here than ever before by about 18 inches. The highest was at about 1 P. M. of the 6th. At 3 o'clock it was falling, and is said to have fallen rather slowly.

At Burnt Mills, on Lamington river, it commenced to rise about 7 A. M. and reached the highest at 3 P. M., rising very rapidly from 1 to 3 P. M. It did not get back to the normal until the forenoon of the 8th. Below the dam it was about 11½ feet higher than ordinary stages. It came up faster than ever known before.

At Vliet's Mills it began to rise at 7 A. M., and rose very rapidly from 12 to 2 P. M., at which time it reached the highest. It remained up about one hour, then commenced to fall, reaching the normal about 48 hours after the beginning. It was 10 feet above the ordinary height of the river.

At Pottersville it was observed to be rising at 10 A. M., and reached the highest at 2 P. M. From 10 to 11:30 A. M. it rose 18 inches. It did not begin to go down until 4 P. M., and was over about 36 hours after the beginning. The rise was very rapid, and the fall at first rapid and afterwards more gradual. The maximum rate appears to have been nearly 80 cubic feet per second per square mile from the 38 square miles of catchment. It is considerably reduced by the extensive flats above Chester furnace.

There are strong indications from data which we have at hand that the maximum rate of flow from the 192 square miles of catchment of the North Branch was not less than 100 cubic feet per second per square mile, or about the same as that of the South Branch. The North and South Branches both reached their maximum discharge at about the same time, and from about 4 to 5:30 P. M. they were both pouring immense volumes of water into the main stream above Raritan. It was largely on account of this coincidence of the time of highest water on the two branches that the rise lower down was so rapid from 5 to 11 P. M., particularly at about 5 o'clock, although it is to be noted that there was a period of extremely rapid rise almost everywhere on the various streams, and the initial cause of this was the sudden rush of water from the melting snows, combined with the heavy rainfall. It was generally remarked that the snow gradually became saturated with water, and then the whole seemed to go off together to the streams, the snow disappearing in a very short time.

At the dam below Bound Brook, the total volume of the flood during 72 hours was 5,600,000,000 cubic feet, or 2.74 inches upon the catchment of 879 square miles. The maximum rate of discharge here was 59,500 cubic feet per second, or about 68 cubic feet per second per square mile. The volume of discharge in September, 1882, amounted

to 6,489,000,000 gallons, or 3.36 inches upon the catchment, while the maximum rate was 52,000 cubic feet per second, or 59 cubic feet per second per square mile. The flood at this point, however, was restrained, as it all had to pass through the opening afforded by the dam, which is guarded by a high earthen embankment across the flats to the east. It could not reach its maximum discharge until the valley above had filled up to a height which would enable it to pass the dam. The actual discharge of the valley above into the pond between the dam and the mouth of the Millstone river was at a much more rapid rate. We find that from 5 to 11 P. M. there was an average rise in this portion of the river of 8 feet, and the accumulated water represents a volume of 421,000,000 cubic feet, which is equal to a discharge of 19,500 cubic feet per second during the period of 6 hours, but during the same period there was discharged at the dam an average of 39,300 cubic feet per second, consequently the average discharge from the catchment into the portion of the stream between the dam and the mouth of the Millstone during these 6 hours was 58,800 cubic feet per second, or nearly as much as the maximum rate at the dam where that maximum was sustained for only a short time. It is plain that this high rate of average discharge during these hours indicates an actual maximum much higher than that recorded at the dam. We have at present no means of ascertaining exactly what the unrestrained maximum discharge would have been with the river free from all artificial obstructions, but it could not have been much less than 85 cubic feet per second per square mile. By measuring up carefully the volume of water in the river at different times between the junction of the North and South Branches and the dam, we are enabled, however, to estimate the volume of discharge at the end of given periods during the flood. Thus, about 11 P. M. we find the volume of water in the valley was 1,814,000,000 cubic feet, and up to that time there had been discharged at the dam 1,220,000,000 cubic feet, giving as the total yield of the water-shed during the first 12 hours 3,034,000,000 cubic feet, or 1.5 inches in depth upon the catchment. In the same way we find, for the first 24 hours, a yield of 4,222,000,000 cubic feet, or 2.1 inches upon the catchment, and in 48 hours the valley was practically free from water, so that the discharge at the dam at that time represented the actual flood discharge, and amounted to 4,964,000,000 cubic feet, or 2.43 inches upon the catchment. In 72 hours it was, as already given at the dam,

5,600,000,000 cubic feet, or 2.74 inches upon the catchment. Of course it does not follow that the water would have been discharged at this rate during the first 24 hours, as even without any artificial obstructions whatever there must still have been a considerable accumulation of water in the valley, although it would have been materially less.

A study of the slopes assumed by the flood at different stages, along the valley, is instructive and interesting. Thus, at 5:30 P. M. the river had reached its height at the junction of the North and South branches, when it stood at an elevation of 64 feet above sea-level, and about 18 feet above the ordinary height of the river. But at this time at the mouth of the Millstone it had only reached a height of 9.5 feet above the river, and an elevation of 29.5 feet above the sea. This shows that at that time there was a fall of 34.5 feet in 8 miles. At the dam the river had risen 7.5 feet or to an elevation of 24.5 above sea-level, showing a fall of 5 feet in 4 miles. This rate of fall was apparently preserved quite uniformly until after the flood had reached its maximum. Between South branch and the mouth of the Millstone, however, the slope gradually decreased, and at 9 P. M. the river had fallen to an elevation of 60 feet at the junction, and risen to 33.5 feet elevation at the mouth of the Millstone, and 28.5 feet at the dam. At 11 P. M. it had fallen to 59 feet at the junction of the branches, and had risen to 37.2 feet at the mouth of the Millstone, and 32.2 feet at the dam. At 9 A. M. of the 7th it had fallen to 58.5 feet at the junction of the North and South branches, to 33.2 feet at the mouth of the Millstone, and 29.2 feet at the dam. During the period from 5 to 11 P. M., therefore, we notice that in the section of the valley above the mouth of the Millstone the water rose about 8 feet at the lower end, and fell 5 feet at the upper end. This shows the passage of what is often called a flood wave, although the term seems a little misleading. A true wave is caused by the impingement of some body, such as the air in motion, or a body of water from a bursting reservoir upon another comparatively still and motionless body of water, and a true wave produces almost no forward movement of the waters. It is merely a vibration or vertical motion of the particles. A rapidly rising river, such as the Raritan at this time, if confined to about the width of its channel, would have a velocity proportional to the square root of its depth. As the depth in this case at 5:30 P. M.

was 18 feet at the upper end, and about 7.5 feet at the mouth of the Millstone, the velocity would be in the proportion of about three above to two below, which would tend to cause an extremely rapid rise, and something similar to a tidal "bore" in the case of a confined channel, but in this case the river had to fill up the meadows on either side before it could advance with a depth of 18 feet down the valley, and this filling up of the meadows was constantly abstracting water from the stream in large amounts, tending to retard its movement down the valley to a very considerable degree. Nevertheless, the effect of this movement was undoubtedly seen in the extremely rapid rise noted along the valley and at Bound Brook about 5 P. M. On the falling flood, as the river recedes, it has to draw back to itself again the large volume of water stored on the flats. Indeed, where a stream rises and falls as rapidly as does the Raritan, the bordering flats are frequently of little account in passing the flood down the valley. All of the effective work, or nearly all, is accomplished directly over the channel of the river. The movement on the meadows is mainly at right angles, or nearly so, to the stream. It will be noted that at no time during the progress of the flood was the fall above the mouth of the Millstone less than about 22 feet in 8 miles, or 2.75 feet per mile. If we should take the entire average cross-section of the flood through this part of the valley and compute the discharge with this slope, it would be found to be vastly in excess of the greatest actual discharge which occurred. We have often found in making such studies as this that the channel of the river itself, with the depth at the maximum and the observed slope, would carry the entire flood-discharge. This fact explains why it is possible to encroach so largely upon the flood cross-section of a river without disastrous results, provided that such encroachment is made after a careful study and in a judicious manner. The lessons of the flood under discussion in the Raritan valley, however, are very clearly to the effect that there is a serious amount of injudicious obstruction of the river. The areas of bridge and dam openings are often inadequate, and still oftener the bridges are injudiciously located, so that the opening is not effective. Instances have come under our observation where bridges caused back-water to the extent of three or four feet during this flood, and this condition of things not only causes much additional damage through the valley, but is perilous to the bridges, as the scour resulting from

the high velocity undermines piers and abutments. The fault is not confined to any one class of structures. Many of the highway bridges are inadequate, but here the fault is often less serious because the approaches are lower, allowing the water to run around the bridge to a considerable extent. When a highway or railroad bridge is approached on embankments thrown across the valley it should be given a waterway sure to be ample for all contingencies. On all branches of the Raritan, excepting the Millstone, the present flood shows that 100 cubic feet per second per square mile may be expected at times, and on some of the smaller branches this will be considerably exceeded. Floods of this magnitude on the main stream will not be of frequent occurrence, as we have had not more than four which approach it during the century, but on any given branch they may be looked for oftener, because of local conditions, such as very heavy showers, &c. A considerable amount of litigation has resulted from the alleged insufficiency of waterway of bridges, and other artificial obstructions, which it is claimed impeded the passage of the flood of February 6th.

Musconetcong River.—The Musconetcong drains 158 square miles of the Highlands, about one-half of which is in the glaciated portion and 39 per cent. is forest-covered. The stream is a long one, having only short branches evenly distributed along its lower thirty miles. The present flood exceeded the maximum recorded in the Report on Water-supply very materially. It was impossible to get exact measurements on the lower portion of the stream, but some fair approximations convince us that the rate of discharge was not more than 45 cubic feet per second per square mile. A good measurement of the run-off was obtained at Lake Hopatcong from the filling of the lake. For the first 24 hours the discharge amounted to 2.37 inches, and for 48 hours 3.01 inches, upon the catchment, which measures 21.6 squares miles exclusive of the water area of the lake, or 25.4 square miles in all. This shows a rate of discharge greater than that of the South Branch of the Raritan from its larger water-shed of 67 square miles.

At Waterloo the maximum discharge amounted to 2,284 cubic feet per second, and at Saxton Falls just below it was 2,295 cubic feet per second. The catchment at this place measures 68 square miles, and about 85 per cent. is forested. The measurements here and at Waterloo show that the run-off in 24 hours amounted to 1.12

inches, in 48 hours to 2.27 inches, and in 72 hours 3.73 inches upon the catchment, which is taken at 68 square miles less 31 square miles caught and retained by Lake Hopatcong and Stanhope reservoir, or 37 square miles net. The maximum flow observed is at the rate of 64 cubic feet per second per square mile, making a new and much higher record than any heretofore given. This was the lowest point on the Musconetcong at which such a complete record could be obtained.

The beginning of the rise was noted generally along the stream as having occurred at 8 A. M. of the 6th, while the highest point was reached at Waterloo at 1 P. M. of the 6th, the stream remaining stationary until about 10 A. M. of the 7th. At Hackettstown the highest is said to have occurred about 2 P. M. of the 7th, but below this it occurred everywhere on the 6th, at Beattystown about 3 P. M., at Stephensburg from 12:30 to 3 P. M., at Pennville at 1 P. M., at Changewater at 4 P. M., at Hampton at 3 P. M., Asbury, 2 P. M., and below that from 5 to 5:30 P. M. The time was carefully noted and verified, and is interesting as showing that the time of highest water at successive points going down stream is not regularly later than points above, but is modified by local conditions. This is peculiarily interesting because this stream has no large branches between Waterloo and its mouth. It follows from this, almost necessarily, that the rate of discharge at the maximum is not proportional to the catchment, a fact which we have frequently noted and explained. Similarly we find a disagreement at different points on the stream as to whether this was or was not higher than previous floods. It was said to be the highest ever known at Waterloo, Hackettstown, Beattystown, Stephensburg, Pennville, Changewater, Asbury, Bloomsbury and Reigelsville, by amounts varying from one to four feet at the different places. At Finesville it is said that a flood in 1838 was nearly as high, while at Hampton one in 1857 was thought to have been about as high. At Changewater the flood of 1857 was claimed by some to have been one foot higher. The stream did not reach its normal condition until about four days after the beginning.

Pequest River.—The notes made along the Pequest river show that the depth of snow was from 7 to 8 inches; that it became saturated with rain about 10 A. M., of the 6th, and two hours later it practically disappeared. The river responded in its usual quiet manner, and the maximum flood-flow at Belvidere did not exceed the previous highest

of 12.5 cubic feet per second per square mile, but the stream remained high about a week. This condition of things is due to the large area of flats or meadows on the catchment, and the Pequest presents the same conditions as the Passaic above Little Falls, but on a much smaller scale. A flood in 1869 is said to have been as high as this, but there must have been several others equally high. The stream began to rise everywhere about 9 A. M., and had reached its highest at Belvidere at midnight, and at Tranquillity about the same time, while between Townsbury and Belvidere the highest occurred about 5 P. M. This highest stage came from the rush of water from the lower watershed. Above Tranquillity, near the headwaters, the highest point was still later than at Tranquillity. In its extreme slowness and lower maximum rate, the Pequest is a striking illustration of the paramount influence of topography upon the rate of flood-discharge. The catchment has only 18 per cent. of forest.

Paulinskill.—On this stream it was noted at several points that the snow was from 6 to 8 inches deep on the morning of the 6th, and quite firm or solid. It became saturated about 11 A. M., and had practically disappeared at 1 P. M. The stream began to rise slowly about 8 A. M., and at noon the water is said to have come down with a rush. A flood in October, 1869, was from 12 to 14 inches higher than this one at Balesville, and at most other points it is said to have been of about the same height. At Warrington the maximum rate was 4,068 cubic feet per second, which exceeds the maximum recorded on page 104 of the Report on Water-supply, and amounts to 26 cubic feet per second per square mile. At Paulina, where the catchment is 126 square miles, the maximum recorded was 6,734 cubic feet per second, or 54 cubic feet per second per square mile, and we find that the total flood-discharge for 72 hours amounted to 2.92 inches, of which 2.31 inches went off in 48 hours, and 1.2 inches in 24 hours.

MAXIMUM RATE OF DISCHARGE.

February 6, 1896.

Catchment.	Area in square miles.	Percentage of forest.	Cubic feet per second per square mile.
Raritan	879	13	68
Passaic	822	58	22
Pompton	285	76	65
South Branch	276	13	100
Paulinskill	175	27	26
Ramapo	160	75	54

Catchment.	Area in square miles.	Percentage of forest.	Cubic feet per second per square mile.
Pequest	158	18	13
Musconetcong	130	30	45
Paulinskill	126	27	54
Rockaway	118	82	43
Ramapo	86	80	56
Wanaque	73	85	99
South Branch	67	30	113
Pequannock	48	78	115
Whippany	38	36	84
Musconetcong	36	85	64
Dumont's Brook	10	5	140

In this table, wherever the flood has been held back by storage reservoirs, the maximum rate of flow is taken to be that of that portion of the catchment not affected by such holding back. Such correction has been made on the Pompton for the storage reservoirs of the East Jersey Water Company and for Greenwood lake. But several other natural lakes upon the catchment have not been allowed for, so that the maximum rate for the Pompton is undoubtedly still reduced by these other lakes. The maximum rate on the Pequannock is taken to pertain only to the portion of the catchment below the East Jersey storage reservoirs. For the Wanaque the catchment has been reduced by throwing out the part controlled by Greenwood lake, although nothing is allowed for Sterling lake. The Musconetcong maximum is also corrected by throwing out the portions of catchment controlled by lake Hopatcong and Stanhope reservoir. The maximum rates of discharge here given are consequently sufficiently accurate to admit of comparison. The table is convenient for ready reference and general comparison, but without allowing for local pecularities no useful lesson can be learned from it as to the effect of forests upon flood-flow. The maximum rate of discharge measured in this way is effected by purely local conditions, mainly by the shape of the valley at the point where the measurement is taken. The velocity of discharge down the valley is determined by the depth of the water and the slope of the valley above the point of gauging. It is also affected to a less degree by the capacity and slope of all the valleys of the catchment. Where these are flat, so that the water can spread, no great depth can be attained, and the rate of discharge is consequently lower. The retarding effect of forests, if any exist, would be better shown by the rate at which the water comes in

to the valleys from the surrounding slopes. Thus, on the Raritan, we determine by taking the accumulation of water between the dam below Bound Brook and the mouth of the Millstone, that for six hours the water was discharged into this portion of the valley at a rate which averaged almost as high as the maximum recorded for a short time at the dam, and from this we must infer that the maximum rate of discharge into the valley above the dam was much higher. On two water-sheds exactly similar in topography, the rate of discharge will be greater as the size of the watershed is less. This fact appears throughout the table, and allowing for this it is impossible to detect any relationship between the maximum rate of discharge and the percentage of forest on the catchment. The same conclusion was reached in the last annual report by comparing the maximum recorded discharge of a large number of streams. It is rather better shown now from the fact that we are comparing these streams in a flood under almost exactly similar conditions everywhere. The relative height of a flood, as generally understood, and its destructiveness, are accurately measured by the maximum discharge above shown. On two catchments fairly similar in topography, one of which is largely forest-clad and the other deforested, the forest-clad watershed should show a lower rate of flow if forests exert a controlling effect upon floods. The Ramapo at Pompton and the Paulinskill at Hainesburg seem to be fairly comparable. The former with 75 per cent. of forest shows a maximum rate of 54, while the latter with 27 per cent. of forest shows a maximum rate of but 26. Again, the upper Ramapo with 80 per cent. of forest shows a maximum rate of 56, while the Wanaque with 85 per cent. of forest shows a rate of 99, and the Pequannock with 78 per cent. of forest a rate of 115. The Pequannock shows about the same maximum rate as the South Branch at High Bridge, although the latter has only 30 per cent. of forest. There are enough of such instances to entirely break the force of the cases in the table which seem to show a higher rate for a less percentage of forest, such as the Pompton and the south branch of the Raritan, or the Whippany and Upper Musconetcong, and the conclusion is inevitable that any effect which forest may have had upon the maximum rate of discharge is entirely subordinate to other controlling influences which we have stated to be mainly topographical.

The destructive character of the flood under consideration, which in most places seems to have been higher than any previously recorded,

has, as usual, been freely attributed to deforestation. We repeat our caution that the mere fact that a flood is higher at a given point than heretofore, does not mean necessarily that its rate of discharge was greater, but may mean that the valley has been artificially obstructed during recent years by bridges, dams or embankments. Admitting, however, that this flood generally had a higher rate of discharge, the question at once arises, why, if this is due to deforestation, the effect has not been felt much earlier. We pointed out in the last annual report the absolute dearth of evidence either that the area of forest is less, or that its condition is in any way inferior to that of 1850. Indeed the evidence is all to the effect that the country is less deforested at present than it was 45 or 50 years ago. The long interval which has elapsed since the deforestation seems to prohibit the direct inference that the more violent discharge was due to that cause.

The only positive evidence which we have is found in the relative rates of discharge of various catchments under different degrees of deforestation. Returning to the analysis of this evidence the following table presents, in a more satisfactory way than the foregoing one, data which may indicate retardation of the discharge by forest, if it exists:

DISCHARGE BY PERIODS.

In inches on catchment.

Catchment.	Area in square miles.	Per cent. of forest.	Discharge in given hours from beginning.			
			12	24	48	72
Passaic at Dundee	822	58	0.10	0.36	1.13	1.72
Raritan at dam	879	13	0.41	1.48	2.43	2.74
Passaic at Two Bridges	773	58	0.61	1.55	2.37	2.72
Raritan above dam	879	13	0.63	1.59	2.43	2.74
Pompton	350	76	0.71	1.55	2.42	2.89
Ramapo	160	75	0.54	1.34	2.62	3.13
Paulinskill	126	27	0.39	1.20	2.31	2.91
Rockaway	118	82	0.44	1.21	2.08	2.50
Ramapo	86	80	0.55	1.32	2.54	3.01
South Branch	67	30	1.13	1.73	2.60	3.12
Pequannock	63	78	1.42	2.45	3.22	3.53
Musconetcong	37	85	1.12	2.27	3.53	3.73
Lake Hopatcong	22	94	.....	2.37	3.01	.....

PERCENTAGE OF TOTAL DISCHARGE.

By consecutive periods.

	First 12 hours.	Second 12 hours.	First 24 hours.	Second 24 hours.	Third 24 hours.
Passaic	23	34	57	30	13
Raritan	23	35	58	31	11
Pompton	25	29	54	30	16
Ramapo	17	26	43	41	16
Paulinskill	13	28	41	38	21
Rockaway	18	30	48	35	17
Ramapo	18	26	44	40	16
South Branch	36	19	55	28	17
Pequannock	41	29	70	22	8
Musconetcong	30	31	61	34	5

In the first of these tables the figures first given for the Passaic at Dundee and Raritan at dam are for flow locally restricted. In the case of the Passaic this comes about through the operation of the extensive flats and the restricted outlet at Little Falls, while in the case of the Raritan it is due to the dam itself and other artificial obstructions. In the figures next given for the same streams this is corrected, the Passaic figures being also corrected to allow for water stored in lakes and reservoirs, and we have the rate at which the water came in immediately above the point of restriction. These two, together with the Pompton, represent catchments large enough to be free from local and accidental features. The discharge by periods does not show any effect traceable to forest conditions, indeed, the rapidity of discharge is somewhat greater on the well-forested Pompton catchment, and the figures are nowhere higher than for the well-forested Pequannock. In general the discharge in inches of depth for the first day will be greater as the area of catchment decreases. This law is well exhibited in the 24-hour period. Taking the whole 72 hours the volume of flood-discharge is seen to vary materially on different catchments. This may be due to local differences in the amount of rain or snow, or in the absorbent power of the soil. It does not appear to be less on the forested catchments. In order to eliminate the effect of differing volume of total discharge the second table is made up to show what percentage of the total was discharged during the first and second 12-hour periods and during the three 24 hour periods from the beginning. In these tables the agreement between the forested Passaic and deforested Raritan catchments

is striking. The Pompton, being a smaller catchment, naturally shows a little higher rate for the first 12 hours. But it is about four per cent. less during the first 24 hours, this four per cent. having been carried over and discharged during the third day. We are of the opinion that this slight retardation is attributable to the lakes and ponds entirely. That it is not due to the high percentage of forest seems proven from the fact that on the Ramapo, one of the branches of the Pompton, having about the same percentage of forest, the retardation is considerably greater than on the Pompton. Lakes and ponds operate also in the case of the Rockaway to produce a similar result. The South Branch of the Raritan shows a more rapid discharge than the foregoing streams, but less rapid than the much better forested Pequannock and Musconetcong, showing clearly that the difference is chargeable mainly to the decreasing size of the catchment, and not to deforestation.

The flood of 1896, therefore, so far as indicated by our studies, is one of the extreme floods which occur at long intervals from peculiar meteorological conditions, and it seems that these studies verify the results of our previous investigation, from which we drew the conclusion that forests had little or no effect in retarding the extremely high floods. The beneficial effects are apparently confined to the more usual stages of the river, as we pointed out in the last annual report.

PART VI.

Drainage of the Hackensack and Newark Tide-Marshes.

BY

C. C. VERMEULE.

Drainage of the Hackensack and Newark Tide-Marshes.

BY C. C. VERMEULE.

The tide-marshes commonly known as the Hackensack and Newark meadows extend in a continuous belt about 18 miles long, and with a general width of four miles, from Elizabeth northeastward to Hackensack and Englewood. The Newark meadows, lying between Elizabeth, Newark and Newark bay, have an area of 7,289 acres, mostly within the limits of these two cities. The Hackensack marshes have a total area of 20,045 acres, of which 1,465 acres, lying between Hackensack and Wood Ridge, is not tide-marsh but fresh meadow. With this exception, the total of 27,334 acres is tide-marsh, lying at, or slightly above, the level of high tide. Occasionally an unusual high tide submerges the whole area, and it is always in a saturated condition. The marshes have a soil consisting, for the larger part, of blue mud or clay, but portions are the bottoms of former cedar swamps, are of a peaty nature and contain many logs, roots and stumps. The depth of mud has been sounded by this survey, and the results of the sounding are given in the accompanying map. By far the greater part shows a depth ranging between 10 and 15 feet, although there are considerable areas where the depth is only from 4 to 8 feet, or even less, and also small areas showing over 20 feet. In its present condition practically all of this area is unproductive. It raises a luxuriant crop of coarse sedge and salt grass having little value. It is a breeding-place for mosquitoes and other insects. Owing to its trifling value this marshy area is gradually becoming, and is likely to, in the future, become more and more a site for offensive manufacturing industries, manure piles, and other nuisances. The marshes are crossed by 12 important lines of railway, 6 of which are trunk lines, and all of which carry a large and rapidly increasing suburban passenger business. On this account these unattractive-looking and neglected marshy areas are continually under the eye of many hundreds of thousands of people, and undoubtedly create in the

stranger's mind an unfavorable impression of what is really the most rapidly growing and desirable residence district in the vicinity of New York. Notwithstanding the phenomenal growth of this part of the State, these marshes have consequently had a retarding influence upon its progress, and their improvement to such an extent as would transform them into grazing lands or market gardens could not fail to have a decided beneficial effect upon the real estate value of this whole district. Aside from the direct benefit resulting from a removal of a blot upon an otherwise fair landscape, it is a well-known fact that the nuisances attributable to these marshes are experienced by all of the populous country lying east of the Orange mountain, and extending from Elizabeth, on the southwest, to Paterson, Hackensack and Englewood on the northeast. The population of this territory in 1895 aggregated 900,000 people. It has increased very steadily during the last half century, at a rate of 40 per cent. each ten years, and sometimes at a rate exceeding this. If we assume this rate to continue, the population 25 years hence will be fully two million, and indeed it is plain to one fully acquainted with the growth and possibilities of this territory, that so long as it continues to keep pace in transportation facilities and attractiveness with the western end of Long Island and the district beyond the Harlem river, its growth must continue at an extremely rapid rate, probably exceeding any predictions which we have ventured to make. The assessed valuation of this district is at present $430,000,000, of which about $340,000,000 is the assessed valuation of real estate alone. We believe that no single improvement would do more to enhance the comfort and prosperity of this large and wealthy community than such a judicious and moderate improvement of these marshes as we shall attempt to outline. The figures of assessed values, which we have given, show that a very moderate percentage of increase in the real estate values of the whole district will repay the cost of the improvement.

The potent reasons for urging an improvement of the marshes are those which we have indicated, namely, the health and comfort of this large population bordering upon the meadows, the increased attractiveness of the whole district as a place of suburban residence, and, if the improvement is carried forward on proper lines, the increased facilities for conducting the growing commerce and manufacfacturing industries of what must eventually become a vast city. We consider the benefits of an agricultural nature, or the enhancement of

the value of the marsh land itself for agricultural purposes, as something which should be regarded as incidental, yet they should not be entirely ignored. Until it shall be needed for buildings and business purposes, this large area of over 27,000 acres, with markets lying at its very doors, or everywhere within easy driving distance, thus saving all freights, must have a very considerable value for dairying and market-gardening. If drained it will at once begin to attract manufactories along the banks of the waterways, where excellent sites are offered but are now unavailable because of mosquitoes and unfavorable sanitary conditions.

There is no doubt that the most economical and advantageous way would be to have the district improved as a whole under the direction of some single board or governing body. The cost per acre of embanking and draining, as a rule, decreases as the area or the scale of operations increases. As there may be insuperable obstacles to the accomplishment of the work in this way, however, we have thought well to outline the subdivisions of the marsh lands into smaller districts which might be operated upon by private enterprise or by the communities most directly interested. By whatever organization the works shall be installed, it should be kept in mind that they will be of such a character that their continued good condition and efficiency can only be secured by leaving them permanently in charge of some controlling organization which can employ proper technical skill and exercise intelligent supervision. Such drainage works cannot safely be left in charge of the parties who might happen to be, for the time being, the owners of the reclaimed lands. It is not merely the reclamation of the marshes that is aimed at, but the sanitary and other benefits which will accrue to the whole district, and the permanence of these benefits must be insured by proper supervision. It ought also to be kept distinctly in view that this work is for the good of the surrounding community as a whole, and it not infrequently happens that some other township or county than the one in which the marshes happen to be situated has a direct interest in their improvement. On this account it becomes especially desirable that the work shall be done as a whole and shall be under a common administration in the future. The actual method of procedure and organization by which the work may be accomplished can only be suggested in outline. It is the aim of the present article to point out with some definiteness how the engineering work should

be planned and executed in order to secure the greatest benefits, and also to furnish the necessary data and suggestions needed to inaugurate such an improvement.

We have considered three methods of reclaiming these lands, which have been suggested at different times. The first is filling-in by dredging open canals through the marsh, the dredged material to be used in raising the intervening lands above the level of high-water. Such work could be executed mainly by machinery. A canal 100 feet wide at top, and 12 feet deep, with side slopes of two base to one perpendicular, would furnish material enough to raise a strip of meadow 300 feet wide about 3 feet. About three-quarters of the meadow area would be reclaimed, the remaining one-quarter becoming water surface. The cost could probably be reduced as low as 10 cents per cubic yard of filling, or $484 per acre filled three feet deep. It would lie between this and $700 per acre, according to the circumstances. We consider that this method of reclamation has but a limited application. Such a treatment would be suitable along the banks of the Passaic and Hackensack, where material could be obtained either by widening the river channels and deeping them, or by dredging basins and slips. Especially so, since the best treatment of the water-front along these comparatively narrow rivers, in order to give accommodation to the increasing commerce of the future, would be to provide berths for vessels beyond the limits of the river channel itself, dredging back into the banks for this purpose. Aside from such limited application, this method of improvement is not desirable. The dredged water-channels would undoubtedly be expensive to maintain in good condition, and it would be very difficult to keep up a proper circulation of water so as to preserve good sanitary conditions. Especially where the ground is likely to be occupied by cities, such open waterways would be extremely objectionable, an obstruction to land traffic and a menace to health.

FILLING.

The next general method of improvement is raising the meadows by filling with extraneous material, either ashes and other solid refuse from the cities, or earth brought in for the purpose, or the combination of the two. A certain amount of such filling can be done gradually along the outskirts of cities bordering on the marsh, with the waste-material of the city itself, at a very small cost, and no doubt a

large amount will be done in this way, as has been done already. Where material is brought in for the purpose, the cost will usually be not less than 25 cents per cubic yard, which amounts to about one cent per square foot of surface for each foot in depth filled, or $1,200 per acre filled 3 feet deep. The actual depth of filling will vary from 3 feet upward, according to the grades established and the necessities of drainage, &c. It would probably average 6 feet, and the settlement of the marsh would increase the necessary amount of material. Land reclaimed by this method would cost on the average $2,500 per acre. While it may be applied gradually to land required at once for building, it is too costly a treatment for any very considerable part of the large area with which we are dealing. We must recognize that it will be a long while in the future before all this land will be needed for city uses, and such an expensive method of treatment should not be applied more rapidly than the land is actually needed, as the interest charges upon the cost would be burdensome. Meanwhile if the large area of tide-marsh not needed at once for buildings does not receive some method of treatment which will render it more attractive, the growth of the whole community will be, to a certain degree, retarded.

Even at the estimated cost of $2,500 per acre, filling would not do away with the necessity for pumping the sewage, as we could not obtain sufficient fall across this wide extent of marsh to dispose of the sewage by gravity. Ultimately the larger part of the rainwater would have to be included with the sewage upon areas which came to be used for city purposes, consequently there would be no important saving in the cost of maintenance to offset the heavy cost of filling, if the filling should be applied to large areas.

EMBANKING AND PUMPING.

The third method of treatment considered is the one which has been usually adopted wherever reclamation has been successfully accomplished on a large scale. It is embanking, or dyking, and draining the water off by means of tide-sluices, or by pumping. Notable examples of this method of treatment are found in the drainage of fen-lands of England and in the very extensive system of drainage-works of Holland. In our own State it has been successfully applied in the counties of Salem and Cumberland for agricultural purposes. These last works have not been so successful in recent years owing to

the rather depressed condition of agriculture and a consequent failure to follow up the drainage and keep it in a proper state of efficiency, but for many years they were very notable examples of successful and profitable reclamation. The drainage there has invariably been effected by the simple process of shutting out the tides with earth embankments and draining off the water by means of tide-sluices. The ordinary tide sluice consists simply of a wooden gate hinged at its upper edge and hung so that it will open when the water inside, in the meadow ditches, is slightly higher than the water without, thus allowing the water to flow out freely, but immediately closing when the current sets in the opposite direction. By means of such sluices, where the amount of water flowing into the meadow from tributary streams is not too large, the water in the meadow ditches is kept down nearly to the level of low tide. As our tide-marshes are usually a little higher than ordinary high tide, and about five feet higher than low-tide level, they are kept amply well drained in this way so long as they retain their natural level. Experience in this State and elsewhere has shown, however, that where the marshes are of a peaty nature, drainage and tillage results in a steady shrinkage or subsidence of the level of the marsh, and this subsidence continues until the marsh becomes as low as low-tide level, or lower if the drainage is continued and the water pumped. Many instances of this shrinkage were observed during the leveling operations of the Topographic Survey, thus the natural level of Hackensack meadows was found to be from about 2.3 to 2 75 feet above the level of mean tide; but east of Harrison, near the turnpike, in the portion of the marsh which was embanked by the New Jersey Land Reclamation Company about 1869, the marsh had subsided in 1887 to .9 of a foot below mean-tide level, or something like 3½ feet below its normal level. Embanked meadows in Cape May county and near Mays Landing had subsided about one foot. On Cohansey creek, in Cumberland county, some were observed which had subsided from 2½ to 3 feet, and in Salem county instances were noted of a subsidence of 3½ to 4½ feet, the latter being within 6 inches of the level of low tide. Such a subsidence must be recognized in the designing of drainage-works of this character. When it takes place, drainage by sluices in the way we have indicated gradually ceases to be effective, and the water must thereafter be removed down to a lower level by pumping.

Sometimes this settling of the marsh to which we have referred has been successfully counteracted by opening the meadow to the tides,

and allowing the water to flow in and deposit its sediment. Where streams carry a considerable amount of silt, the marsh can be built up in this way quite rapidly. It has been done in two ways. One was to keep the tide shut out for a period of years and continue the cultivation of the meadows, then to open the banks and allow the tide to flow in during another period of years and deposit the sediment and fill up the meadow. Of course such a method as this could not be entertained at all where the drainage is mainly for sanitary purposes, as it will be on the Hackensack. Another method, and one which has come to be preferred by the owners of such improved meadows, is to allow the tide to flow in each winter, and secure in this way enough deposit to keep the meadow up to a proper level for drainage. The waters of the Hackensack river would in any case be of little value for this purpose, as the amount of sediment carried is not large; those of the Passaic might be more useful, but it is not likely that such flowage would be much resorted to on the Hackensack meadows.

The accompanying map shows which portions of the meadows consist of blue mud, and which are of a peaty nature. Between these two divisions there are belts of meadow which consist partly of peat and partly of blue mud. The shrinkage of the blue mud will probably be less than for the peaty portions. On the latter it will, of course, be determined largely by the depth of the marsh, and we find that, with the exception of some very limited areas, this depth is generally 8 feet or less. The surface of the meadow may be taken to be generally 5 feet above low-water level, so that it does not seem probable that any very large area of this marsh will sink much below the level of low tide. We must certainly look forward to pumping the water from the entire area drained after the marsh has had five to ten years of shrinkage, as the sluices will then become ineffective; consequently, if sluices are built, they may be of a temporary character, of timber, but so constructed as to be tight and substantial during their probable period of service.

QUANTITY OF WATER TO BE REMOVED.

In designing our sluices, drainage channels, and possibly the pumping-works later on, it becomes necessary to know how much water must be removed, and at what rate. The capacity of the pumps or sluices must be equal to the maximum rate at which the water will come down the drainage channels. The data for determining the rate and amount are found in the Report on Water-Supply, published by this Survey in 1894. The best measure of the rate is found in the flood rates of flow of the neighboring rivers. On page 153 of the Report on Water-Supply there is given a table showing all the floods which occurred on the Passaic during a period of seventeen years. The greatest flood, and one which has not been exceeded, probably, during this century, occurred September 25th, 1882, and the table shows that during eight days the amount of water discharged was equal to 3.71 inches of rainfall on the water-shed. Another flood in 1878 showed a total of 3.47 inches of water running off in eight days, and during the seventeen years there are ten floods exceeding 2.75 inches depth on the water-shed. The duration of the flood was usually eight days, and it seems to be quite clearly indicated that a total of 3.71 inches is not too much to provide for in the light of these facts. As to the period during which this water would run off, however, there are conditions on the large Passaic water-shed which make the time considerably longer than it will be in the case of our smaller areas to be drained. Thus we find that on the Raritan, in this same flood of 1882, there was a total discharge of 3.36 inches in 64 hours, so that from this and observations on several smaller drainage areas, it seems that provision for 3.6 inches depth of water on the entire drainage area during a period of three days, or 72 hours, would be a proper allowance. This amounts to .05 cubic foot per second per acre, or 32,582 gallons in 24 hours for each acre draining into the drainage district in question. This gives us the total capacity of our pumping machinery or tide-sluices, which must be provided to prevent overflowing of the lands in heavy storms. The average amount of water to be taken care of, however, will be very much less. Table No. 54, on page 198 of the Report on Water-Supply, shows in detail how much water will flow off the Hackensack water-shed during each month and year of an average, an ordinary dry, and the driest known year. The following table, based upon the table quoted, shows the daily amount of drainage during each month of the average year:

	Average amount of drainage, Gallons per acre daily.
January	2,580
February	2,590
March	2,470
April	2,110
May	1,730
June	1,200
July	770
August	690
September	730
October	850
November	1,440
December	2,210
Year	1,610

We find from this that 1,610 gallons daily for each acre drained will be the average amount of water to be removed. It must be noted carefully that the total amount will be determined not merely by the acreage of marsh land, but by any additional acreage of uplands, the drainage from which finds its way into the marsh. We must, therefore, provide for emergency a total pumping capacity of 33,000 gallons per acre of marsh and tributary upland each 24 hours, but for six months of the average year, or during one-half of the time, we shall need only a capacity of 1,440 gallons daily per acre, or about five per cent. of our total pumping capacity. The other 95 per cent. will only be used occasionally, and 25 per cent. only rarely. Such conditions of irregular use make the important items in the cost of pumping, the wages and interest and depreciation on the plant, and the fuel item becomes less important; consequently it follows that the best economy will be secured by machinery of moderate cost and moderate duty. The centrifugal pump, for instance, would be well adapted to furnish at least ninety per cent. if not all of the pumping capacity of each station. Pumping has been effected to a large extent in Holland by wind-mills, but the later and more thorough drainage works have almost invariably adopted steam power. Which should be applied must be determined to some extent by the particular case under treatment; thus, a portion of marsh which has within its borders a considerable drainage channel capacity where the drainage-water can be received and held during a period of calms, can be drained by wind-power, but where this is lacking and the drainage must be continuous and constant, it is better to resort to steam-power pumping.

Pumps of the above capacity would cost, for the complete plant, about $10 per acre, supposing the plant to be of sufficient capacity to drain about 1,000 acres or more. If the plant is very much smaller than this the cost per acre would be somewhat increased. We estimate the annual cost of operation of the pumps, including interest and depreciation on the cost of plant, at from $3.35 to $4.10 per acre of drainage, according to the efficiency of the plant, and perhaps $3.75 per acre would be a fair allowance for the cost of steam-power pumping. The cost in Holland has been much less, but there the rainfall exceeds evaporation by only about 8 inches per annum, whereas here the excess of rainfall over evaporation amounts to over 24 inches, or three times as much, which accounts for our larger estimate.

In providing for the removal of the water by sluices we have to bear in mind that the water must be kept down in the ditches from 12 to 20 inches below the surface of the meadow for pasture or grass-land, and from 20 inches to 3 feet for grain-fields. The rise and fall of the tide being 5 feet, if the water could usually be kept within one foot of low-water level, it would be quite low enough to allow for ordinary subsidence of the meadow. Grass could be raised successfully after the meadow had shrunk two feet, without resorting to pumping. Sluices should be set partly below the level of low tide. In order to discharge the maximum of .05 cubic foot per acre, one square foot of orifice should be provided for each 26 acres drained, including all the upland draining into the embanked area. This is on the assumption that the water of the marsh is never to be allowed to rise higher than mean sea-level, and that the sluices will discharge under a head ranging from nothing up to one foot. If this area of sluices is provided the water will be kept at a much lower level usually, and will rarely reach a higher point than eighteen inches above mean low tide. The computation is made, however, on the assumption that the sluices will discharge in a time of floods, for an average of six and one-quarter hours for each tide, consequently they must discharge at a rate about twice as fast as the flood rate, or .10 cubic foot per second per acre.

The ditches within the marsh, on the above assumption, must have sufficient capacity to retain all the flood-waters for a period of 6¼ hours without a rise of more than 18 inches in the water-level. As our flood-rate of 3.6 inches in 72 hours amounts to .3 of an inch in six hours, the area of ditches must amount to $^1/_{60}$ of the entire area drained. In Holland the superficial area of the ditches amounts to

from $^1/_{10}$ to $^1/_{12}$ the area of the polder, which it will be seen is nearly five times as much as our estimate, but this practice may have resulted largely from drainage by windmill power, requiring a larger area for storage. Our estimate refers to drainage by sluices. It should not be less for steam-pumping, as it does not provide more than enough waterway to pass the water freely toward the pumps, and it might profitably be increased in the case of sluices, the rise of flood-waters being correspondingly diminished, but the limit of such diminished height will soon be reached, as it causes a corresponding diminution in the time of discharge. It is doubtful if any increase of ditch area beyond $^1/_{40}$ of the area of catchment would be of substantial benefit. This, of course, includes the entire area of both main and lateral ditches. The main ditches and natural drainage channels ought to provide for at least half of the required channel area.

It is apparent that economy requires as much as possible of the upland water to be excluded from within the banks. Its drainage naturally into the sea may sometimes be provided for by carrying the banks back along both sides of the natural water-courses to the upland and constructing drains along the edge of the upland to divert the water from the marsh. It is also apparent that there will be a considerable increase to the cost of maintenance of the improvement where pumping must be resorted to, but, nevertheless, it will be unavoidable, and when the subsidence of the marsh has made it necessary the improvement should be followed up by steam-pumping; otherwise the marsh will revert to its original condition.

Taking the cost of pumping at our estimate of $3.75 per acre annually, it will be seen that this is five per cent. on $75 per acre. This is far within the cost of filling by any possible method. There can be no valid objection to the method of dyking and pumping, even where the marsh is used for city purposes, for the embankments can readily be made strong beyond any reasonable doubt, and the pumping capacity can be made sufficient to remove the water under all circumstances, so that the drainage within the embanked area will be in all respects as good as on the upland.

DYKING.

The method of embanking which has been practiced largely in Salem county is as follows: A ditch is dug on the site of the pro-

posed bank four feet wide and two spits deep. This removes the sod and grass-roots of the surface, and allows the bank to be closely united with the underlying clay, or other firm material. Then a ditch 12 feet wide and three spits deep is dug along the line of embankment, and from this the material is taken to build the bank. The spits cut out of the trench are cut into small pieces and fitted closely together in the bank by the packer in the same way that stones are laid up in a wall. The mud, when well packed, forms a very strong and durable bank so long as it is kept moist. If it gets too dry the bank will crumble down, but this rarely occurs. The general size of the banks is 4 feet high above the meadow, 8 feet wide at the bottom, and 3 feet on the top. The slope is about one to one on the outside, and about one-half base to one rise on the inside. The steepness of these slopes explains the crumbling referred to. Of course, in exposed stations, such as Finn's Point, along the Delaware river, the banks are built much heavier. The one referred to is 10 feet high, 12 feet wide on top, and 30 feet at the bottom. This bank is also protected by a facing of stone on the river side. The banks are usually built at a little distance from the stream, leaving a strip of marsh outside, a rod or more in width, for the protection of the bank, and also to supply the mud used in repairing. This space is called the guard or fore-shore. The cost of this work has varied considerably, of course, but generally the lighter banks described have cost from two to three dollars per rod, and from ten to fifteen dollars an acre has been expended for building banks and sluices and opening drains and water-courses. Ditches are cut at intervals, varying with the needs of the meadow, and are generally about 7 feet wide and 2 feet deep. The cost for repairs has ranged from fifty cents to $1 an acre yearly, and some of the more exposed banks have cost an average of $2 an acre. Much of the expense is caused by the depredations of muskrats and of the soldier crab, or fiddler. Unusual high tides causing breaks, and the settling of the banks have been additional causes of expense in maintenance. The settling has been slight along the banks of streams, for there the meadow is usually firm, but the cross-banks running back to the upland often settle badly. The softer parts of these tidal meadows are usually found near the edge of the upland, and where the meadows are quite wide this portion is also often considerably lower than the meadow near the streams.

The dykes about the meadow in Kearney township, Hudson county, were built by the New Jersey Land Reclamation Company, about 1869, as we have already mentioned. In this case, in order to guard against the burrowing of muskrats, thin cast-iron plates were inserted in the bank, reaching from about 18 inches above to 3½ feet below the surface of the meadow. This was, of course, a costly expedient.

The general results of the writer's observation and acquaintance with the embanked meadows of the State convince him that the success of the work is, to a large degree, dependent upon the solidity and permanent character of the embankments and tide-sluices. While it calls for a larger capital outlay at first, which is an important consideration where the work is done as a private enterprise, the interest on the increased outlay needed to secure the best work is but a small part of the increased cost of maintenance due to building the works too light. For the Hackensack meadows, we should recommend as the minimum dimensions of the banks, a height of 4 feet above the marsh surface, with a top width of six feet, and slopes on each side of one and one-half base to one perpendicular, making the width of the base of the bank at the surface of the meadow 18 feet. We would also recommend that no turf should be used excepting for the slopes and top of the bank. A trench should be dug 8 feet wide and about 2 feet in depth along the center line of the bank, reaching through the turf and grass-roots so as to secure imperviousness at that point. Instead of the expensive cast-iron core, sheet piling of creosoted lumber 1½ or 2 inches thick, and reaching from about 2 feet above to 4 feet below the meadow level, would be equally effective and much cheaper. The fore-shore, or distance between the bank of the river or creek, should in every case be liberal, and since it is proposed to eventually fill a broad belt of land along the banks of the navigable rivers for use for business purposes, a liberal allowance may as well be made as not. Where the banks are built close to the edge of the stream in exposed situations, they must be built much heavier and protected with stone. Such a bank as we have outlined will require the handling of not less than 3 cubic yards of material per running foot of bank. If the work is done by hand and wheelbarrows, such banks will cost about $1 per running foot, but if done on a large scale, machinery can be used for most of the earth-work, and the cost could easily be reduced below 85 cents per running foot. The sluices should be carefully constructed, but as they will probably

only remain effective about ten years, they may be of timber. When pumping has to be resorted to, they may be filled up. The saving of pumping expenses, for even five years, will pay well for building the sluices, and meanwhile valuable experience may be gained for the design and location of pumping plants. Of course in some exposed places it will be judicious to use somewhat heavier banks, and they will always have to be partially protected with stone facing. Some addition will therefore be necessary to our above prices per running foot. For cross-banks we would recommend about the same dimensions, but sheet-piling could usually be safely omitted. Cross-banks should not cost more than 60 cents per running foot built by hand, or 45 cents by machinery.

PRESERVATION OF WATERWAYS.

Before we can intelligently outline a method of treatment of the marshes, a description of the waterways afforded by Newark bay and the Hackensack and Passaic rivers, and the treatment best adapted to each will be in order. There is an ample channel from New York bay and the Narrows, extending into Newark bay a distance of about one and one-quarter miles above the draw-bridge of the Central Railroad, with a depth of 15 feet at mean low-tide. For the next two miles through the bay to about opposite Passaic Light the depth of the channel is about 8 feet at mean low-water, then it deepens to 10 feet, and proceeding up the Hackensack river after we reach the Newark and New York railroad it becomes 15 feet and upward, and is generally considerably over 15 feet up to the Pennsylvania railroad bridge. From this point to Little Ferry we have sounded the channel and find 15 feet at low-water all the way, with over 30 feet much of the way. The soundings are shown on the accompanying map. The least depth to Hackensack is 7 feet, and 10 could easily be secured, while Overpeck creek could readily be improved to 12 feet depth a distance of two and a half miles above Little Ferry. Berry's creek is navigable for canal boats to the plank road at Carlstadt. The Hackensack has practically 15 feet at mean low-water from the Newark and New York railroad bridge to Little Ferry, therefore, and the deepening of about 4 miles of the channel below the railroad bridge, through the bay, from its present depth of 8 to 14 feet to a uniform depth of 15 feet, is so

evidently feasible that its accomplishment should be looked forward to in the future, when the improvement of the marshes has increased the commerce of the river so as to demand it. The work becomes the more practicable when we consider that the material dredged could be utilized for the projected improvement of the marsh lands. This would give us a waterway extending 18 miles, from the Kill von Kull to Little Ferry, on the Hackensack, right through the heart of this growing district. The Hackensack has a width varying from 1,200 feet to about 500 feet. It will be seen that it affords accommodation for a large commerce, and the water frontage along its course must steadily increase in value.

The Passaic is navigable from its mouth to Passaic City, a distance of 12½ miles. For 4½ miles from its mouth, up to Centre street bridge of the Pennsylvania railroad, its width decreases gradually from about 1,200 feet to 360 feet, and it has been improved to a depth of 10 feet at mean low-water. From the Centre street bridge to Passaic its navigable depth at mean low-water is 6 feet. It preserves a width of about 360 feet to Belleville, and above that gradually decreases. The banks along the upper part of the river are in many places quite steep, and do not not afford very ample room for manufacturing sites. The requirements of commerce will probably be met by a few docks here and there at accessible points, and it would seem that the great natural beauty of the river valley and its rather limited facilities for commerce point to some such treatment as has been proposed for the Charles river in Boston; indeed, it can be made far more beautiful than will ever be possible with the Charles, by means of a well planned system of marginal drives and parks, which should extend all the way from the northern part of the city of Newark into the city of Paterson. Such a line of parkways would add greatly to the attractiveness of the valley after the river has been purified by means of intercepting sewers. We make this suggestion at this time mainly in order to indicate the radically different methods of treatment called for by the two streams, the Passaic and Hackensack, and also to emphasize the great future value of the admirable waterway offered by the Hackensack river. The lower portion of the Passaic, however, up to the city of Newark, is a valuable waterway, and must become increasingly so in the future. We find from the report of the Chief of Engineers, U. S. Army, for 1889, that in 1884 the commerce of the river amounted to

1,200,000 tons, valued at $30,000,000, which by this date must show a very large increase. The same report estimates the traffic of the Hackensack in 1889 to amount to 150,000 tons, valued at $1,000,000, but it is known that this is increasing. That it is not very much larger is due to the fact that the Hackensack, throughout almost its entire navigable course, is cut off from the neighboring populous upland by broad belts of tide-marsh, which make it entirely inaccessible, rendering almost useless its otherwise excellent facilities for manufacturing and internal commerce. One of the great advantages which we claim will come from the drainage of the marshes and their improvement will be the bringing down of the cities to the water front, so that these waterways can be utilized. Those who understand how rapidly and completely the water frontage of Hudson county, on Hudson river and the bay, is being absorbed and utilized, will be the better able to appreciate how valuable the Hackensack must eventually become, and how important it is that these communities should retain control of a reasonable part of its banks for public use.

Newark Bay has a broad channel much of the way, nearly half a mile in width and nearly on its center line. Each side of this there are quite large areas having a depth of less than 5 feet at mean tide and less than 2½ feet at mean low-tide. Considered as a navigable waterway alone, it might seem wise to gradually reduce it to the channel width of half a mile, the general width of the bay being 1½ miles. In view of the extent of marsh, a considerable part of which must eventually be filled up, requiring a very large amount of material, it would seem that the broadest and most rational treatment would be to make the improvement of these waterways and tide-marshes go hand-in-hand. Indeed, it will not be easy to obtain material for filling more cheaply anywhere than by dredging out the bay and rivers. The first step, therefore, would appear to be to dredge and improve the channel through the bay as already indicated, then to obtain material for filling the shallow margins by broadening and deepening it, thus improving both its commercial usefulness and its sanitary condition.

METHODS OF PROCEDURE.

When we come to consider by whom the expenses of the improvement of the marshes should be paid, we find that there are potent reasons why the whole district east of the Orange mountains should

contribute a certain share. It is probable that the improvement is in advance of a time which would make it equitable that the whole cost should be borne either by the owners of the marsh land or by the smaller communities in which the marshes happen to lie. Thus the town of Kearney has within its limits 4,520 acres of tide-marsh, while its population is 10,487, whereas the town of Harrison has but 246 acres of tide-marsh and a population of 9,674. It is readily seen that the interests of the town of Harrison in the improvement of the Kearney marshes is fully as direct and great as the interest of the people of Kearney township, nor indeed is the interest of the large cities of Newark and Jersey City substantially more remote than that of Kearny and Harrison. Nor will the improvement of the marshes within their own borders relieve these cities to any substantial degree so long as the marshes in Kearney and other neighboring townships remain unimproved. So we might go through the whole list, and while we do not by any means wish it to be inferred that it would not often be profitable for the separate townships and cities to improve the marshes within their borders, it is apparent that the desired result—the inauguration of sanitary conditions, the removal of a blemish upon the surrounding country, and the ridding it of mosquitoes and other nuisances—can only be effected by the drainage of the whole tide-marsh area. If we attempt to subdivide the improvement, we find that with any practicable system of subdivision almost every sub-district would require for its treatment the co-operation of two or three towns, boroughs or cities. This is because the subdivisions must follow certain natural divisions without reference to political boundaries.

Some sections of the marshes could undoubtedly be reclaimed profitably by private capital vested with the necessary powers, but we have to remember that the large incidental benefit to the neighboring upland districts is something which could not be realized as a profit to any private parties carrying out the drainage works. For this reason, and because the improvement as a whole may not offer sufficiently prompt returns to be attractive to private capital, it may, perhaps, be regarded a public rather than a private undertaking.

There are but two methods by which the work can be carried out as a whole so as to derive the greatest benefit from it. One is by a Special Commission created by the State, with full powers of condemnation, the right to issue bonds and levy assessments to provide funds, and to do all things necessary and proper to execute and maintain the

improvement. It would probably not be possible to at once raise revenue enough from assessments upon the drained lands to provide for interest and maintenance. It would be equitable that the temporary deficiencies should be assessed upon the surrounding communities benefited, for after a time this reclaimed land would undoubtedly become so valuable as to not only bear the whole cost of drainage, but to add materially to the taxable values of that part of the State.

A second method of drainage is found in an application of the Drainage Law of 1871. Under this law the drainage of any tract of land can be secured on the application of five owners of land therein situated to the Board of Managers of the Geological Survey. This Board then makes examinations, and if the drainage seems to be desirable, surveys are made and plans of drainage adopted. A report is made to the Supreme Court, and it then becomes the duty of such court to appoint three commissioners to superintend and carry out the drainage of such tract. Such commissioners have the right to assess the cost upon the land benefited, and have also the right to issue bonds and borrow money, pledging for the payment thereof the assessments.

It will be noted that this throws the entire cost of the improvements directly upon the marsh lands. Private owners may avail themselves of this law by preparing themselves to take up any of the remaining lands in the tract which may be sold for the assessment. Without such support from private capital, it would have to be clearly evident that the lands to be drained would produce enough money to pay the cost of drainage, if sold by the commissioners for the drainage tax. Unless the tract is marketable immediately at a price which will cover the cost of drainage, bonds issued under this law will not be marketable, and the money cannot be raised to carry out the work. An amendment of this law which will provide some plan of having the neighboring upland communities meet any deficiencies would make it more applicable to the problem under consideration.

Methods requiring the co-operation of the owners of marsh land, or a majority of them, within a drainage district have been adopted to some extent in other parts of the state, but the results have almost invariably been unsatisfactory. Ways are too often found by unwilling owners to obstruct action, and sooner or later the work is abandoned or allowed to fall into a state of inefficiency. The advantages of prompt and uniform execution, and the direction of the work on the broad

lines necessary to secure the inauguration of better sanitary conditions and the greatest future public good, can only be secured by a commission, created according to one of the two foregoing plans, with sufficient power to prescribe general plans and exercise general supervision of the drainage works.

Supposing the existence of a single commission with control of the whole district the following is suggested as a practicable method of procedure: First, plans should be prepared for the treatment of the whole, including marshes, water-front and waterways, and keeping in view the ultimate occupation of the whole area for commercial, manufacturing and residence purposes. The entire marsh should then be embanked and the tides excluded. Drainage may be accomplished for the first few years by sluices, as their cost will be repaid by the saving of a few years' pumping expenses, but the introduction of pumps should be looked forward to and would probably be necessary within ten years everywhere, in some cases sooner. Main ditches should be cut so as to provide everywhere an outlet for the lateral ditches; any interior lands owned in the interest of the improvement could then be sold or leased on condition that they should be cultivated and improved at once, as without this ultimate improvement the sanitary benefits of the work cannot be secured. These will be found good grazing lands when improved, and their utilization for this purpose would be desirable. Lands along the water-front, and probably along railways, would be held for commercial and manufacturing uses. So fast as it could be sold or leased a broad belt along the water-front should be filled level with the top of the dyke. The filling could be obtained by dredging and improving the waterways. It would, perhaps, be preferable that a considerable part of the water-front should be owned by the several communities, and wharf privileges leased. This might be accomplished by the payment of a proper sum by the city in question into the drainage fund. This broad levee sloping back gently to the marsh level, would form an effectual safeguard against inundations and the interior marsh could be allowed to settle to its final level.

By this general method of procedure the improvement need at no time be in advance of the requirements of the particular district under treatment. The embanked lands, as soon as they were utilized and devoted to grazing and market-gardening, would become an ornament instead of a nuisance. The more costly improvement of the water-

front would only be prosecuted as fast as the land could be sold, and would undoubtedly yield a substantial return. Lands along the several railroad lines would become valuable at once for manufacturing uses.

We have made an estimate of the expense of embanking and draining as proposed, the entire improvement being of the substantial character which we have recommended. It must be remembered that if the work is done in this way on a large scale, great economy can be effected by the use of machinery. We consider our estimate liberal:

256,000 feet main bank @ $1.00	$256,000
35,000 feet cross bank @ 60c	21,000
10 sluices, large, @ $10,000	100,000
55 sluices, small, @ $5,000	275,000
900,000 feet of main ditch @ 45c	405,000
Add for contingencies 20%,	211,400
Total	$1,268,400

This estimate shows that the entire 27,000 acres could be reclaimed at a cost which need not exceed one and a quarter million dollars. It does not include the cost of acquiring the marsh land.

The above amounts to about $47.00 per acre, and until pumping becomes necessary we have, at five per cent., $2.35 interest; maintenance may be estimated at $1.00 per acre, making a total of $3.35 annually. When pumping begins it will add $3.75 per acre, making $7.10 in all as the annual charge per acre, to which must be added interest on the cost of marsh land. While the advantages of ample markets within easy-driving distance would give the land considerable value even for agricultural purposes, it is evident that returns must be secured mainly from the portions adapted to better uses, and cultivation will for the most part only yield incidental revenue and maintain the sanitary conditions necessary to make the more valuable portions available for commercial, manufacturing and residence purposes.

Aside from the question of direct profit from the reclaimed land, since the whole cost of reclamation amounts to less than one-third of one per cent. of the assessed value of surrounding real estate, it seems clear that the enhanced attractiveness, sanitary benefits and mitigation of the mosquito pest will be quite sufficient returns for the outlay.

SUBDIVISION INTO DRAINAGE DISTRICTS.

The accompanying map shows the area of marsh under discussion, the depth of mud and its character, the depth of water in the rivers and bays and the elevation of the marsh surface above mean sea-level at the present time. It also shows a suggested subdivision into drainage districts with the lines of dyke, etc. We shall now take up these several districts in more detail than has heretofore been attempted and try to give some practical suggestions for their improvement.

Newark Meadows.—This is the first subdivision of the marsh which we shall consider. It embraces a total area of 7,081 acres, of which 4,003 acres are within the limits of the city of Newark, 628 acres in the township of Clinton, and 2,450 acres in the city of Elizabeth. The area draining into this marsh, including the marsh itself, amounts to 12,900 acres, so that we have to provide for a maximum of 46,000,000 gallons of water daily, and an average of 21,000,000 gallons daily. The marsh consists mainly of blue mud, a portion of it along the borders of the upland being mixed with peat. Most of this peaty area lies north of the Peddie street canal, and west of the Newark branch of the Central railroad. It is in that part of the marsh, therefore, which is likely to be the soonest filled up to be used for building purposes. Conditions are favorable for successful drainage of the district by sluices for a time, to be followed by pumping when shrinkage of the marsh makes it necessary. This district is a good illustration of the advantages of drainage on a large scale, instead of by separate communities; thus, if we should undertake to drain the portion in the city of Newark alone, 49,000 feet of main tide-bank would be necessary, as the bank would extend the entire length of Bound creek. If the meadows are all drained together, however, only 39,000 feet of bank will be required for the whole. If so treated there is no apparent need of cross banks. The economy of comprehensive drainage, therefore, is expressed by the control of 7,081 acres, with 39,000 feet of bank, whereas independent action by Newark alone would require, for the reclamation of 4,003 acres, 49,000 feet of embankment.

The installation of the preliminary drainage-works, consisting of embankments, sluices and main drainage channels, would cost less than our average of $47.00 per acre and would result in great benefit to Newark and Elizabeth. The outskirts of Newark are already advanc-

ing upon the marsh, which is being gradually filled up and built upon. The improvement of that portion within the city limits has already been considered. Taking the tract as a whole, no substantial advantage will accrue from filling it up. Even if filled an average of six feet deep, when it comes to be built upon it will nearly all have to be drained by pumping.

The water-front aggregates 40,000 feet on Passaic river and Newark bay. As the channel of the bay is, on the average, 3,000 feet from the shore, if the bulkhead line is not advanced too far there will be enough material to be dredged to fill the water-front to a good height. None of this area is over a mile distant from a railroad line.

Jersey City Meadows.—Within the limits of Jersey City, and fronting on Hackensack river and Penhorn creek, there are 1,450 acres of tide-marsh. Bearing in mind what we have said as to the possible future value of the Hackensack as a waterway, the improvement of this tide-marsh would give to Jersey City a valuable and what promises to be a much-needed addition to her water frontage. The utilization of this marsh-land has already begun and the filling-in of the portion between the Pennsylvania and the Paterson, Newark and New York railroads is so far advanced that the improvement can be as readily completed on these lines as otherwise, so that this portion will not call for embanking. The narrow strip south of Communipaw avenue and along Morris canal also might profitably be improved by filling without embanking. It may be worth while, however, to embank the portion between Communipaw avenue and Pennsylvania railroad, which has a large area to fill and the filling of which would be in advance of immediate requirements. This includes an area of about 400 acres, which could be reclaimed with about 7,000 feet of main bank and 4,000 feet of cross bank. It could be embanked and sluiced and provided with main ditches at a moderate expense. The 20,000 feet of frontage on the Hackensack river would probably be improved and utilized at no very distant time. With the improvement of navigation on the Hackensack, some considerable relief to navigation and railroad traffic would be afforded if the numerous railroad and highway bridges were raised high enough to admit of tugs and barges passing under. The remainder of the tide-marsh within the bounds of Jersey City we have included in the Penhorn creek district, including all from the Paterson, Newark and New York railroad to the northern line of the city.

Penhorn Creek District.—This district affords another illustration of the wastefulness of any independent attempt to improve the tide-marshes by single communities. It would take more bank to shut out the tides from the portion lying within the limits of Jersey City alone than it would to improve the entire Penhorn creek district from the Hackensack river to the Paterson plank-road. The area of tide-marsh in this district is 2,030 acres, of which 775 acres is within the limits of Jersey City, and the remainder in the town of North Bergen. 12,000 feet of main bank and 4,500 feet of cross-bank will shut out the tides, and the cost should not exceed about $50,000. This land is very favorably situated, and is mostly blue mud. Between Tyler Park and Scheutzen Park there is an area of cedar-swamp bottom. The improvement should be profitable, and would be a great sanitary benefit to the northern portion of Jersey City, West Hoboken and Secaucus, including the county institutions at Snake Hill. It is remarkable that, while near the mouth of Penhorn creek the marsh is at or slightly above mean high-tide level, at the head of the creek, near the plank-road, it is about two feet below. The numerous railroad and highway bridges apparently so obstruct the inflowing tide that it reaches the head of the creek much diminished in height, so that the marsh has shrunk as if embanked. Immediately north of the plank road, at the head of the Cromakill, it is normal, or about at high-tide level.

Secaucus District.—This lies along the east bank of the Hackensack, extending from Snake Hill up to the Paterson plank-road, a distance of 18,000 feet. It would be controlled by 18,000 feet of main embankment and 1,000 feet of cross-bank along the plank-road. The marsh here is about at the level of high tide and its area is 1,250 acres, lying entirely in the town of North Bergen. The catchment is only a little larger than the area of the marsh. The soil is almost entirely blue mud, with a narrow belt of peaty mud near the upland.

Cromakill District.—This includes the remainder of the tide-marsh in North Bergen township, Hudson county, extending from the Paterson plank-road to Bellman's creek, on the east bank of the Hackensack. It lies opposite to Union township, the town of Union, and Guttenberg. The marsh included measures 1,730 acres. At the head of Mill creek and the Cromakill, extending about a mile northerly from the plank-road, the marsh is of a peaty nature, with some cedar swamp; the remainder is blue mud. It would require 21,000 feet of main bank and 5,500 feet of cross-bank dividing it

from the Penhorn and Secaucus districts. It has a frontage of 9,000 feet on Hackensack river.

The marsh, at the head of the creek, near Paterson plank road, is generally level with high tide in Hackensack river, but in some places it is three or four inches lower. It must be remembered, however, that in such cases high water in the creek is also lower than in the river, so that the marsh is not necessarily overflowed at high tide.

Ridgefield District.—This includes all of the marsh between Belman's creek and Overpeck creek east of the Hackensack, together with the isolated marsh at Fairview, an area of 990 acres, lying in the township of Ridgefield, Bergen county, opposite the boroughs of Fairview and Ridgefield. Its improvement would require 21,000 feet of main embankment. It has 13,000 feet of frontage on Hackensack river, and 4,000 on Overpeck creek. A small area on the point between Hackensack river and Overpeck creek has been embanked, but the improvement is not in good condition. The soil is entirely blue mud, varying from 1 to 12 feet in depth, but very little exceeds 7 feet. The shrinkage of the portion referred to as having been embanked was ascertained to be about one foot.

Overpeck District.—The marsh drained by Overpeck creek bounded on the south by the road from Ridgefield to Little Ferry, has an area of 1,395 acres. Of this area 371 acres is in Teaneck township, and the rest practically all in Ridgefield, with some wet-land at the head of the marsh in Englewood township. The total catchment area draining into the marsh measures 17.36 square miles. The water surface of Overpeck creek measures 320 acres. The marsh is very wet and almost entirely worthless at present. It is also a nuisance to the surrounding country, which is otherwise a most attractive district for suburban residence. The mud is 4 to 5 feet deep near the upland, and from 9 to 10 feet deep along the creek.

Two methods of draining the district are possible: First, by embanking along the line of the Ridgefield and Little Ferry road, and building sluices so as to keep the waters of the whole creek down to near low-water mark. As the creek would form quite a large reservoir for the reception of water near high-tide there is little doubt that this scheme would be practicable, but the catchment area is so large that when the marsh shrinks so that pumping becomes necessary there will be a large volume of water to be lifted. It will also be seen, by referring to the map, that the creek affords a very good waterway,

capable of material improvement at a moderate expense. It might not only be made useful, but will become a source of pleasure to the surrounding country. For these reasons it does not seem desirable to adopt such a method of treatment, as holding the water down at low tide-level will almost destroy the creek for these purposes. It seems better, therefore, to carry the dykes along both banks of the creek all the way to the upland. This will permit the discharge of most of the waters from the catchment naturally into the creek, and will reduce the area draining into the marsh to 6.9 square miles, or 4,416 acres, including the marsh area. This will require the removal of an average of 7,000,000 gallons of water daily, while the total pumping capacity must be 155,000,000 gallons daily to provide for storms. This plan will require the construction of 42,000 feet of main embankment, and provision for pumping must be made after the meadow has been under bank a few years. The improvement will cost more than the average for dyking, and less for ditching, but, on the whole, will somewhat exceed our average of $47.00 per acre. The improvement would be of very great value to the fine residence district stretched along the Palisades from Ridgefield to Englewood, as well as to the neighborhood of Ridgefield Park on the west side.

Polifly District.—This district, lying just east of Hasbrouck Heights and Woodridge, is entirely inland. It is really a fresh meadow or peat bog, the mud or peat being generally of slight depth, much of it lying directly upon a light-yellow sand. Many sandy hummocks project above the peat on the east side of the marsh. The elevation of the surface, as shown on the map, is practically everywhere 18 inches above high-tide level, and near the head and east side of the marsh it is from three to four feet higher than the level of mean high-tide. A moderate raising of the highway from Moonachie to Woodridge to exclude extremely high tides, and the introduction of ample sluices at the head of Berry's creek, together with a thorough ditching of the whole area, seems to be all that is necessary to secure good drainage. The total area of catchment, including the marsh, amounts to 2,900 acres, so that we need about 110 square feet of sluice-opening. A ditch has been dug across the highway referred to, to drain the eastern side of the marsh into Berry's creek, but if the Berry's creek tide-marsh district is to be improved, it would be preferable to abandon this ditch and drain the whole area through one outlet at the head of Berry's creek. Another ditch has been dug from the extreme eastern

border of the marsh across the intervening upland to Mudabock creek. This ditch, also, does not seem very efficient or necessary, and if the Mudabock district is to be improved, it might be preferable to abandon this also.

The cost of embankments and sluices will be lighter than the average, and in fact will be a small item. The main cost will be for ditching, and the total improvement ought not to exceed about $20 per acre for the main ditches and sluices. It is not thought that pumping will ever be necessary. The improvement would result in great sanitary advantage to Hackensack, Hasbrouck Heights and the towns on the ridge to the west. Quite a considerable amount of the eastern portion of this marsh has already been brought under cultivation, but no systematic attempt has been made to drain the whole.

Mudabock District.—This lies at the west bank of the Hackensack and extends from Little Ferry to the Paterson plank-road. The area of marsh is 1,550 acres, of which 192 acres are in Lodi and the rest in Bergen township. There is some wooded swamp, including a considerable amount of white cedar, and measuring 170 acres. Most of the soil near the river is blue mud, but a sprinkling of stumps and snags indicates that perhaps one-quarter of the area on the upland side is old cedar-swamp bottom. The improvement of this district will require 18,000 feet of main dyke and 3,500 feet of cross-bank, the latter following the line of the Paterson plank-road. It is possible that with a slight improvement this road itself might be made the cross-bank. The entire catchment area amounts to 2,100 acres, including the marsh. The average amount of water to be raised when pumping becomes necessary will be 3,381,000 gallons daily, and we shall need a total pumping capacity of 69,000,000 gallons daily to provide for heavy storms. The district could be improved at the average cost. Small portions have already been imperfectly embanked near the Paterson plank-road, and also near the north side of the marsh. Hay is cut on most of the district. The frontage on Hackensack river measures 18,000 feet with deep water throughout, as shown by the accompanying map.

Berry's Creek District.—This extends from the borders of the Polifly and Mudabock districts to the southwesterly line of the borough of Rutherford, and is mostly drained by Berry's creek. The district is traversed by the Erie and New Jersey and New York railroads. Berry's creek is navigable for canal barges to a point above the Pater-

son plank-road. There is also over 10,000 feet of frontage on the Hackensack river. The area of marsh is 3,078 acres, which includes 390 acres of growing cedar swamp, and perhaps 300 acres more of old cedar-swamp bottom. The remainder lying on the Hackensack and Berry's creek is blue mud, and has a promising soil for improvement.

If we keep in mind the drainage of the Polifly district by sluices at the head of Berry's creek, and the preservation of the creek itself for navigation, it would seem best to extend the dykes along both banks of Berry's creek up to the Polifly sluice. The dykes would therefore consist of 3,500 feet of cross-bank on the line of the Paterson plank-road and common to the Mudabock district, and 52,000 feet of main dyke along the banks of Hackensack river and Berry's creek, with 3,200 feet more of cross-bank common to this and the Kingsland district, and running from Berry's creek to the upland on the line between Rutherford borough and Union township. This district ought to be improved for about the average of $47 per acre. The area of catchment, including the marsh, amounts to 4,300 acres, while we shall have an average of about 7,000,000 gallons daily, and a maximum of 140,000,000 gallons daily to be removed. The improvement of this district would open up much property which must become valuable. It would also result in an important sanitary advantage to the growing boroughs of Rutherford and East Rutherford. The height of the marsh in this district is sufficient to make sluicing effective for a time, but after the first five years it is probable that pumping will become necessary.

Kingsland District.—This district includes the marsh west of the Hackensack river, and between the southwesterly boundary of the borough of Rutherford and Saw-mill creek, which is the line between Bergen and Hudson counties. The soil consists of blue mud near the Hackensack river, and blue mud mixed with peat near the upland. The area of the included marsh is 2,170 acres. It has a frontage of 8,500 feet on the Hackensack and about 8,000 feet on Berry's creek. It is traversed by the Boonton branch of the Delaware, Lackawanna and Western railroad. One of the dykes of the New Jersey Land Reclamation Company runs along the south bank of Saw-mill creek from the Hackensack river nearly to the upland. The tides have been rather imperfectly excluded from the portion of the district southwest of the railroad by sluices across the mouths of

Saw-mill creek and Kingsland creek and a tide bank along the Hackensack. The railroad embankment seems to be depended upon to exclude the tides from the northeast, but it does so only imperfectly. The result of this improvement has been to dry the marsh to a considerable extent, and it has shrunk so that it will be seen by elevations on the map to be about one foot lower than mean high-water near the Hackensack river and about three feet lower near the upland. In consequence of this shrinkage the satisfactory improvement of this district can only be accomplished by pumping. It will be necessary to repair slightly and extend the bank along Saw-mill creek, also to strengthen the bank along the Hackensack and extend it northerly to and up Berry's creek. Three thousand two hundred feet of cross-bank from Berry's creek to the upland will be common to both this and the Berry's creek district. The work will therefore consist of moderate repairs of 15,000 feet of cross-bank and of 4,500 feet of main bank, and the building of 13,000 feet of additional main dyke along the Hackensack and Bergen creek. The pumping plant must also be installed immediately and the sluices at Saw-mill and Kingsland creeks may be closed up and the tides permanently excluded. The area of catchment, including the marsh area, amounts to 3,300 acres, so that we must provide for the removal of an average of 5,300,000 gallons daily, and 109,000,000 gallons daily during heavy storms. The map shows the original depth of mud in this district to be 7 or 8 feet near the edge of the upland, and from 14 to 23 feet near the Hackensack river. These depths are at present reduced by shrinkage of the marsh to the extent of about 3 feet near the upland and 1 foot near the Hackensack.

Kearney District.—This includes the marsh in Kearney township between the Passaic and Hackensack rivers, embracing an area of 4,520 acres. It is most advantageously situated, having a frontage of 28,000 feet on the Hackensack river, and about 15,000 feet on the Passaic. It has the growing towns of Kearney and Harrison immediately adjacent to the west, and lies directly in the path of travel between Newark and Jersey City. It is crossed by the Pennsylvania; Delaware, Lackawana and Western; Paterson, Newark and New York; and Greenwood Lake railroads; and also, at its southern extremity, by the Newark branch of the Central Railroad of New Jersey. It is also crossed by the highways leading from Jersey City to Newark, both of which are traversed by electric railways. The

facilities for communication are therefore the best. The district is interesting, because of the attempt made to reclaim it by the New Jersey Land Reclamation Company about 1869. The operations of this company seem to have been interfered with by a decision of courts that they could not exercise powers of condemnation. The work on this district was quite vigorously prosecuted, and the whole was enclosed with substantial dykes furnished with sluices. A considerable part was immediately brought under cultivation, but since that time the whole marsh area has steadily deteriorated and is now in a saturated condition. The banks are kept in fair repair, so that water is usually held about three feet lower than mean high water in the river. The marsh, however, has itself shrunk over three feet, and is now only two or three inches above the ordinary level of the water in the ditches. While it would appear that the water might be kept somewhat lower with more ample sluice area, it is nevertheless perfectly clear that satisfactory drainage of this district can now only be accomplished by pumping. The dyking and ditching seems to have been well done, and a moderate expenditure would put the embankments in good order. The ditches also need to be extended into the northern part of the district. The outlay now required on embankments and ditches is comparatively a small one, but a pumping plant should be installed immediately, and by this means the marsh could be brought under cultivation to improve its sanitary condition. As soon as this is accomplished the portions along the water-front and along the railway lines would rapidly come into the market for manufacturing and commercial purposes. The water-front should ultimately be filled up to the level of the top of the dykes in the the manner which we have outlined as the proper one for this whole improvement. Including the upland draining into this marsh, we have 5,200 acres of catchment, which gives us an average of 8,400,000 gallons daily to be pumped. The maximum during heavy storms will be 170,000,000 gallons daily.

The depth of the mud was originally 7 to 9 feet north, and 9 to 17 feet south of the Pennsylvania railroad. The map shows the original depth. The shrinkage of the marsh has now reduced this depth to an average of 3 feet. About three-fourths of the area is an old cedar-swamp bottom, and the balance mainly along the rivers is blue mud more or less mixed with peat.

PART VII.

Report on the Iron-Mining Industry.

With Notes on the Active Mines.

BY

GEORGE E. JENKINS, C. E.

Iron Mines.

Notes on the Active Iron Mines.

BY GEORGE E. JENKINS, C.E.

In reviewing the iron-mining Industry of New Jersey, it is plain that the facts commented upon in the report published in 1891 are even more strikingly apparent, and that the number of actively-operated mines is constantly decreasing. But on the other hand, it is noted that a constantly increasing output is being obtained from the mines in operation.

Many of the mines now idle have been forced into this condition because of the extremely low prices of iron ore and the general business depression throughout the country.

It is, no doubt, true that the demand for Jersey ores, for use in the furnaces in eastern Pennsylvania, has been very much lessened by the immense quantities of cheaply-mined ores from the Lake Superior region, and the market heretofore exclusively controlled by the product from Jersey mines is now being supplied from other sources.

That there is still a future for the New Jersey mines is clearly demonstrated, inasmuch as the mining enterprises have been able to meet the strong competition and to a considerable extent hold on to the market, though laboring under so many serious disadvantages.

In the past five years only the old and well-known producing mines have been operated, and in these it is noted that every improvement in mining methods and machinery has been adopted, and as a consequence New Jersey ores are cheaper per unit of iron than any competing ore in the Lehigh market.

The mines operated since the last notes were published in 1891 are comprised in the following review:

SHOEMAKER MINE.

This property was in operation until about two years ago, when it was closed, as the company was not able to meet the prevailing prices for iron ore. The Thomas Iron Company used the ore and it was a desirable product, but the item of a three-mile haul to the railroad, coupled with the royalty, did not leave enough margin of profit to warrant continuing operations.

BELVIDERE MINES.

The numerous mining operations in this section have all ceased, and the only mines that have yielded any considerable ore have been the Queen and Fellows mines.

Up to about three years ago the Sharon Ore Company operated the Queen mine, but the low prices in the iron market compelled the company to shut down.

FELLOWS MINE.

The Thomas Iron Company worked this mine until August, 1893, when the lease was surrendered. The work was carried on through the two shafts referred to in the annual report of 1891; the eastern shaft was upon the main deposit, and the working developed a paying body of ore, but much difficulty was met with in holding the ground, owing to the disintegrated character, or rather, complete absence of a solid hanging-wall. The whole formation showed that there has been considerable surface disturbance, and accordingly in carrying on the mining operations the timber expenses were consequently high.

The ore is rich, yielding about 59 to 60 per cent. metallic iron, after washing, and running about 0.07 per cent. in phosphorus and about 9 per cent. moisture. At the time the mine was stopped its product could not be produced cheaply enough to meet the prices then prevailing in the iron-ore market.

OXFORD MINES.

The mines of Oxford were operated up to March 16th, 1895, when active mining ceased, owing to the failure of the Oxford Iron and

Nail Company. The mines, furnace and mill plant were all recently bid-in under a foreclosure sale by the D., L. & W. R. R. Co. During the period of re-organization the mines have been kept free from water, and are in condition to produce ore at a short notice. The opening, designated Slope No. 3, has now reached a depth of over 700 feet in the ore deposit. Some developments to the west were made, and the working area consequently increased to over three hundred feet along the length of the vein. In this distance the deposit keeps its width as developed in the older workings of the mine, and runs from ten to thirty feet. The walls are extremely irregular, and the ore intermingles with the rock to such an extent that careful separation by hand is necessary to make the product yield from 53 to 55 per cent. of metallic iron. It is low in sulphur, and just fails to pass the Bessemer limit in phosphorus.

The workings in the Washington mine are about as reported in 1891. Its product is high in metallic iron, but carries so much sulphur as to require roasting. A very excellent neutral mill-iron is obtained from the mixture of these two ores, and the product in the form of bar-iron was in good favor in the iron market.

The mines will be put into active operation as soon as the organization is perfected.

About 20,000 tons are mined from each deposit per year.

KISHPAUGH MINE.

The old Kishpaugh mine continued its course to the southeast across the adjoining Cook farm, and the workings as now carried on are upon the last-mentioned property. This remarkable deposit of ore is more than 2,000 feet long on the strike of the vein, but in about 1,000 feet of this distance the ore has been removed. From the bottom of the Cook shaft, at a distance of 350 feet from surface, a drift has been driven for 170 feet, where the heading was stopped in ore. In the old workings, the vein had a width of over 25 feet, and the tests made in the above drift proves that the vein keeps its width. In order to still further test the continuity of the deposit, a diamond-drill hole was put down 500 feet west of the Cook shaft, and the vein was encountered at a distance of 400 feet from surface. The walls in the deeper workings are much firmer than in the Kishpaugh mine, and there is an entire absence of any surface disturbances having taken

place at the present deepest working. The ore is somewhat more compact than that taken out in the upper part of the deposit, indicating that the mine is to such depth as to be below surface disturbances. All the machinery has been left in the mine, and every precaution taken to protect the pole-pumps and leave everything in the best possible condition for the time when better prices would rule the ore market and warrant the resumption of mining operations. About 1,000 tons of ore are now in stock at the mine. The ore was last used at the Franklin Furnace, Sussex county, and gave a yield, after washing, of over 52 per cent. metallic iron, and low enough in phosphorus to pass the Bessemer limit.

HURDTOWN MINE.

In August, 1893, the lease of this mine changed hands, and the Glendon Iron Company, which operated here uninterruptedly for more than forty years, gave way to the Mt. Pleasant Mining Company. The bottom workings had reached, in 1895, a depth of about 5,500 feet, measured along the slope, which has an average pitch of 25 degrees. At this point, which is about 1,000 feet below sea-level, the vein became so "stringy" and so much rock had to be handled in order to secure the ore, that it did not pay to operate, and consequently the bottom workings were abandoned. At the same time that the mining operations were being carried on in the bottom, considerable ore was obtained from the sides and roof of the old workings along the incline. In the previous operations, the ore overhead was left standing in the form of an arch, in order to support the cap-rock and hanging-walls; this ore is now being removed and the mine robbed of all that can be obtained from these places. The "robbing" was begun at a point 3,200 feet below surface and has been continued upward to about 2,200 feet from surface. At 800 feet from the mouth of the incline the old workings were so extensive that the method of removing the ore by stages and long ladders could not be carried on, and in order to reach the ore in the "back" some other method of mining had to be devised.

It is very certain that the working-life of this remarkably productive mine has come to an end, and the ore now taken out is "robbed" from old workings, preparatory to abandoning the main part of the mine. Some prospecting for new deposits, as well as tests for the

continuity of the old, has been made, but without success. Test-pits to the east of the old mine developed some ore, but all was in "float" deposits. The monthly product of the mine has very materially fallen off, but this is mainly due to the time consumed in getting the workings in shape for the present plan of attack upon the ore in the roof and sides of the old workings.

WELDON MINES.

The Weldon mines have both been worked but a short time for the past five years, and are looked upon as abandoned mines. While the product of these mines is very desirable, it was found to exist in such limited quantities, as the mines are deepened, that it did not pay the operators to continue mining.

FORD AND SCHOFIELD MINES.

These two mines, though owned by different corporations, operate upon the same veins. There are two veins running parallel and separated by a horse of rock, varying in thickness from 2 to 12 feet. In the Ford mine the south vein has been worked out, and the bed-rock which forms the floor of the shoot has also been reached in the Schofield. The ore in the north vein has not all been taken out in the Ford mine, and only very little mined upon this vein in the Schofield. It has an average thickness of over six feet. At the time the Schofield closed down, sufficient development had been made to demonstrate that there is a long lease of life for the mine, and the low price of ore was the principal cause for the company ceasing operations.

The material is not very rich in metallic iron, but by careful hand-culling it is shipped as a 52 per cent. ore. It is rather high in silica, but is low in phosphorus. The sulphur in the form of pyrites is variable, going as low as .016 and as high as 0.75. About 1,500 tons were mined from the surface workings of the Ford mine during the year by William Sedgeman, but the margin of profit was too close to warrant the continuation of operation. The mining plant of the Schofield is being removed and shipped to the company's works at Catasauqua, Pa.

OGDEN MINE.

The extensive concentrating plant of the New Jersey Concentrating Company has been running from time to time, and work of an experimental character has been carried on. The mining consists in quarrying down the lean, magnetite bearing rock to the east of the old shafts, furnishing a material carrying about 20 per cent. of metallic iron. This is crushed and separated, producing a material in the form of a briquette that runs about 68 per cent. metallic iron; very little work has been done, however, in the way of legitimate mining, and as no shipments of ore are yet made, the works must still be looked upon as of an experimental character.

HACKLEBARNEY MINES.

Only small quantities of red ore have been mined, as the price for the product from these mines has been so low as to offer no inducements to the owners to continue operations.

HURD MINE AND NEW STERLING SLOPE.

The New Jersey Iron Mining Company has continued its operations in the New Sterling slope, and has worked the vein to a depth of 950 feet, on a dip of 45 degrees. As these workings are in the eastern extension of the "Old Sterling Shoot," the dip and strike conforms to that found in the old No. 13 workings. The present workings have been extended to the eastward as far as the old Harvey offset, which is found to continue its course in these greater depths. To the westward the explorations have been continued for about 300 feet, and the present stopes are about 400 feet from the old workings in the No. 13 mine.

At the present bottom a cross-cut is being driven to strike the Hurd vein, and it is calculated that the distance to be driven is 150 feet. The present vein is large, reaching a width of 30 feet, and is followed until it diminishes to such a width as will not allow profitable working.

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face of the stopes then being worked. The slope was saved, and in order to secure it more thoroughly five "log houses" were built—two on the western side and three on the eastern side. Plate 21 represents the workings, and shows the relative position of the workings in the old No. 13 mine when operated and abandoned by the Thomas Iron Company.

The ore is a 60 per cent. non-Bessemer, and of a very open grain.

The concentrating-mill, having a capacity of thirty-five tons per day of ten hours, is continued in operation, and all the lean material culled from the vein is put through and crushed down to a quarter-mesh sieve, giving a product, after concentration, that runs 60 per cent. metallic iron. The experiments with the lean magnetic ores from "Dutch Hill," owing to the expense of hauling, were not entirely satisfactory, in a commercial sense, and consequently the plan of working-up this ore was not continued.

ORCHARD AMD MOUNT PLEASANT MINES.

The estate of J. Couper Lord has not done any mining in the Orchard mine for the past three years, as the high phosphorous character of the ore prevented its finding a market excepting at exceedingly low prices.

Work has been continued in the Mount Pleasant mine, though for the past two years it was plainly apparent that the old Mount Pleasant vein was giving out. These workings at the time of the abandonment had reached a depth, on the dip of the deposit, of 1,400 feet, being about 350 feet below sea-level.

The vein was then so small and "bunchy" and the amount of "dead work" necessary to secure the ore was so great that it did not pay to continue mining. At the most easterly shaft a test for the further continuation of the ore-shoot was made in the shape of a rock-sink, which was put down to a depth of 150 feet, but without striking any ore in paying quantities. Tests were made in the western end of the mine at a depth of about 600 feet, vertical measure from surface, and a drift was driven westward 800 feet, when a well-defined and strongly marked offset was met with, throwing the vein to the south into the hanging-wall a distance of 70 feet. It is plainly evident that this is the same offset which is shown in the outcrop of the Mount Pleasant vein at the foot of the hill, about 1,000 feet east of the public road.

On the western side of the offset the vein opened to from 15 to 20 feet wide, and back stopes were carried upward for 300 feet, and along the strike of the vein for 500 feet. The offset, however, has completely changed the chemical character of the ore, and while it still continues rich in iron, the element of phosphorus is so high as to be detrimental, and the market became so limited that the mine had to be shut down and abandoned. The vein in the west side of the offset is the same as the Orchard mine vein, and it can be worked through this opening very much cheaper than through the Mount Pleasant slope. The cost of pumping the immense body of water, 1,000 gallons per minute, which drained into the abandoned eastern workings, and the long underground tramming and hauling and re-handling of the ore product would not warrant the plan of taking out the ore in the western end of the mine through the Mount Pleasant slope. In consequence of this the entire works have been abandoned and the extensive mine plant is now being sold and shipped away.

RICHARD MINE.

The large and continuous output of this mine has been one of its remakable features for years, and during the past year the product has been very materially increased over its past record. The main workings are about the same as when last reported upon, excepting an increased depth. At the western end of the mine, however, the rock which cut out the vein in the adjoining Baker mine has been developed, and the working area of the vein consequently somewhat shortened. The Eastern shaft, known as No. 3, is now 800 feet deep. on a dip of about 65 degrees. The No. 1 and No. 2 openings are 450 and 580 feet deep respectively. At a depth of 400 feet from surface and 80 feet east of No. 1 slope a cross-cut driven into the foot-wall 350 feet, opened upon the old Mount Pleasant vein, which was found to be 9 feet wide. A considerable amount of back-stoping has been carried on in opening this vein, and it is now made to yield about 4,000 tons per month. A slope to the west of the No. 1 slope, and known as No. 4, has been opened on the Mount Pleasant vein, and the present yield of Mount Pleasant ore is taken from this slope. Recently some explorations were made in the foot-wall of the old mine between opening No. 1 and No. 2, and about 550 feet below surface. The test shows that what has heretofore been considered the

foot-wall is a "horse" of rock of about 2 feet thick, and lying upon a deposit of ore over 17 feet thick. Plate 22 represents the plan and elevation of the mine. At the point "a" the drift into the foot-wall was begun, and the cross section of the mine at this point shows that the small ore-body in the upper level shown in drift "b" is the same ore-body as developed in the drifts at the points "a" and "c" in the lower level—the veins having opened out in width.

Not only does this conformity of the dip of the wall at the points "a," "b," and "c" lead to this conclusion, but an examination of the wall, as exposed, proves the correction of these inferences. The rock of the "horse" is made up of vein material and conforms to the type of rock designated by Mr. Nason as the "Oxford type," while the rock of the true foot-wall is of the "Mount Hope type."

As a further test a drift was driven in the bottom of the foot-wall at the point "d," but at this date the work has not been carried far enough along to encounter the ore-body. The rock through which this drift is driven is more of the character of vein material than country rock, and this fact would indicate that the ore-body continues, but is at an increased distance from the old workings. The two drifts along the foot-wall at "a" and "c" shows the ore-body to continue toward the westward, and in all probability it will extend to the point "e" and "f," where a disturbance of considerable extent has taken place in the main body of ore, forming a "roll" in the foot-wall of the vein, the ore-body in the old workings at this point being very much diminished in width, but only on the foot-wall side, for an examination of the hanging-wall shows it to keep its course without any material change. Further developments will be awaited with interest.

The No. 3 shaft being in a rather unsatisfactory condition, and not being located to the best advantage to remove the new deposit of ore lying on the foot-wall, a new rock-shaft has been planned, which is located in the foot-wall, 30 feet north of the vein and going down on a dip of 52 degrees; it is 15 feet long by 6 feet wide, and divided into 3 compartments. Cross-drifts will be driven from the slope to the vein, the pillars in the old workings removed, and the walls allowed to cave in. The slope being in the solid rock of the foot-wall will not be endangered by the removal of the entire ore product in the vein.

The character of the ore is the same as heretofore reported; the product from the Mount Pleasant vein does not reach the standard of

purity found in the Mount Pleasant Mine, and its chemical composition is very similar to that of the Orchard mine ore, which is the western extension of the Mount Pleasant vein; the ore runs 56.17 metallic iron and 0.85 phosphorus.

The regular Richard mine ore is 2 or 3 per cent. higher in iron, but about the same in other respects as the Mount Pleasant ore. The monthly product is now over 11,000 tons.

MOUNT HOPE MINES.

The last work done in this vicinity was in June, 1893, when the mines were closed. The large stock of ore then on bank has been shipped, and this comprises all the work that has been done during the past three years in these once active mines. The entire running plant is kept intact, and a brisk market is all that is needed to open the mines.

BEACH GLEN MINE.

About 500 tons of ore have been mined from near the surface during the past year. It is the intention of the Beach Glen Mining Company to carry on more active operations in the spring. The ore deposit is large and can be mined cheaply, but the product does not run very rich in iron, but it is low enough in phosphorus to be a Bessemer ore.

HIBERNIA MINES.

The Lower Wood mine has been actively worked by the Andover Iron Company, the present owners, and a large quantity of ore removed. The deepest workings are now 860 feet below the mouth of the pump-shaft, and the length opened in the course of the vein is about 1,800 feet. In 1886 a pinch or barren strip in the vein developed in No. 8 level, and this characteristic of the ground has been working to the eastward, cutting out a large amount of heretofore abundantly ore-yielding territory. In all probability this is the bed-rock of the main Hibernia vein, for while the explorations have been carried on through this ground for a distance of over 200 feet at right angles to the pitch of the rock, no paying ore-bodies have been discovered. The pitch of the rock, being 27 degrees, conforms with that

of the ore shoots, and this would indicate that it, in all probability, is the bottom rock of the main ore-body. The working area of this mine has been increased, however, because of the gain on the eastern end of the property.

The vein in the old Glendon lot has by the dip been carried over to the property of the Andover Iron Company. In addition to this area, the Andover Iron Company has leased that part of the property on the Scott lot which lies between the eastern workings of the Lower Wood mine and the eastern boundary-line of the Glendon lot, if continued to the southward. During the past year the monthly product of the mine has been very materially increased, and if the demand warranted it the annual yield would have been very much above any past yields.

The mine is thoroughly equipped with an excellent plant. Plate 23 represents the workings of the mine in elevation, and shows the pillars, timber, and method of supports. The ground lying east of the incline and between the underground railroad level and level No. 5 is now inaccessible, owing to extensive caves which took place six or eight years ago. The incline was in danger from the movements of these walls and, in order to insure its security, "log-cabin" supports of Georgia pine were built along the line. These have taken up the weight of the ground and prevented any further movements of the old workings. Experimental supports of brick and masonry and iron columns were tried, but they all failed under the heavy strain.

The Glendon Iron Company has mined only upon the Upper Wood lot, and these operations have only been for a short time. Of the several mines owned or leased by this company, the old Glendon mine has not been in operation since 1892, and is practically abandoned, as the bottom of the mine is about sixty feet from the southeast boundary line. This company's lease upon the Scott or Church mine was surrendered some time ago, and no mining has therefore been done since the surrender of the lease. The DeCamp was last worked by the Glendon Iron Company, and in 1888 the lease was surrendered, owing to the high royalty. The shoots of ore which have been developed shows this mine to be the most promising along the line of the Hibernia deposits. At the time the mining operations ceased the bottom stope showed a vein of clean ore ten feet thick. The workings are 500 feet deep and extend along the course of the vein for 660 feet.

In the Upper Wood mine operations were resumed in the fall of 1895, after a period of nearly three years of inactivity. The working length of the mine is 990 feet, and the deepest point 540 feet below tunnel level, or 840 feet vertical distance from surface. The No. 6 shaft was entirely re-timbered and a new skip hoist-way was constructed and in operation at the time that the failure of the company caused the mines to be shut down.

An extensive crushing and concentrating mill was built by the Becket Foundry Machine Company for the Glendon Iron Company, and some 6,000 or 7,000 tons were treated. The plant cost $53,000. and is equipped with the best and most modern crushing and separating machinery. The material put through the mill runs about 40 per cent. metallic iron, and is crushed down so as to pass through a twenty-mesh screen.

Very satisfactory results are claimed to have obtained from the Ball and Norton separators, the concentrates analyzing 60 per cent. metallic iron and the tailing showing a loss of a little over seven per cent. The operators claim that they are able to produce such concentrates at a very good margin of profit.

WILLIS MINE.

This mine, now known as the Wharton mine, has been in continuous operation for the past six years, reaching a depth of 950 feet. The eastern extension of the Hibernia vein, as here operated upon, was narrow and tight in the shallower workings, but the present stopes show that the vein is widening out, and the output consequently increased from a monthly product of about 2,000 tons to over 4,000 tons; the ragged though firm walls still continue, but the "slabby" make-up of the hanging-wall is equally as characteristic as in the old workings in the mines to the westward. During the past year a drift was driven in the eastern end of the mine through what was heretofore considered the cap-rock of the vein, and it proved that only a pinch had occurred, for, as the drift was driven further eastward, the vein widened out. This drift has added about 225 feet more to the working length of the mine. Improvements have been made in the mining operations, consisting of a new skip-hoistway 950 feet long; a new hoisting-engine, capable of hoisting 2½ tons, at a speed of 600 feet per minute.

The ore yields 58 per cent. metallic iron and is used at Wharton Furnace, Port Oram, but as the furnace has been out of blast most of the year the product of the mine has been stocked at the mine and only one-quarter of the mine's capacity has been taken out. The Hibernia ore is especially fitted for making pig-iron, suitable for use in basic open hearth process for steel manufacture, and both the Andover Iron Company and Mr. Joseph Wharton have been having satisfactory results from this use of Hibernia ore.

RINGWOOD MINES.

The group of mines at Ringwood consists of four shoots of ore, each enclosed by well-defined cap and bed-rocks, and having a general strike to the northeast and a dip to the southeast. The No. 1 shoot has been worked to a depth of 800 feet, slope measure, and the ore-body had pinched to such an extent as to make the removal too costly for the present ore-market and it has consequently been abandoned. The pillars, however, are being taken out by removing the hanging-wall, and operations are carried on under the same plan as at the Tilly Foster mine, in New York State. The Nos. 2 and 3 shoots are still large and paying bodies of ore, and as long as there was any demand for the ore operations were carried on upon these two ore-bodies.

The No. 4 shoot has only been opened at its outcrop and developments made there show that the deposit is a promising one. It is the purpose of the owners to resume operations in the spring.

As the result of the review of the iron-mining industry of our State, as shown from the information gathered from the foregoing notes, the fact is very prominently brought out that the mines of our State are not the remunerative enterprises that they have been in years gone by. A combination of circumstances has led up to this result, such as the low price now in the iron market, the high royalty demanded by property owners, the increased cost from deep mining, the high phosphoric character of the ore, and in some cases the long haulage to railroads.

The prevailing panic has been the cause of the closing of the Kishpaugh, Oxford, Belvidere, Hackelbarney, Mount Hope, Schofield, Hibernia, and Ringwood mines, and for many years these mines have been the largest producers of ore.

No new discoveries of ore in merchantable quantities have been developed in the past twenty years, with possibly one or two exceptions, and there is no question of doubt but what the prospecting has been thorough and complete as far as carried on. The impetus to searching for new deposits, however, has not been at all strong, and the continued low value of iron ore has completely strangled any attempts on these lines.

The new process of making steel, known as the basic open hearth process, and which is becoming such an active competitor with the Bessemer process, will probably open a wider field for the ores high in phosphorus. The large deposits of such ores extending from Irondale to Mt. Hope and in fact almost the entire product from the New Jersey mines is of the proper chemical make-up for use under this process.

There are also several large deposits of lean ores low enough in phosphorus to pass the Bessemer limit and capable of being used for making Bessemer steel, but the low percentage in iron has been the great drawback to their being used in this process. Thus far it would seem that no economic process had yet been devised by which these ores can be profitably concentrated and made available for use.

The concentrating mills of Port Oram, Weldon, Hibernia and Ogden are examples of attempts at solving the problem, but it has in no sense been definitely and clearly shown that the concentration of New Jersey magnetites is a commercial success.

ZINC MINES.

STERLING HILL.

The Passaic Zinc Company mines consist of two openings upon the deposit, and its deepest workings are now 600 feet below surface. The deposit has a length of 400 feet, dipping to the southeast at 60 degrees, and both hanging and foot-wall are well defined. The ore is about 22 per cent., and is smelted at the company's works at Jersey City. The mine is well equipped with the most modern mining-machinery, consisting of hoisting and pumping-engines and Cornish plunger-pump, having a 5-foot stroke and plunger 10 inches in diameter, and a lift of 170 feet.

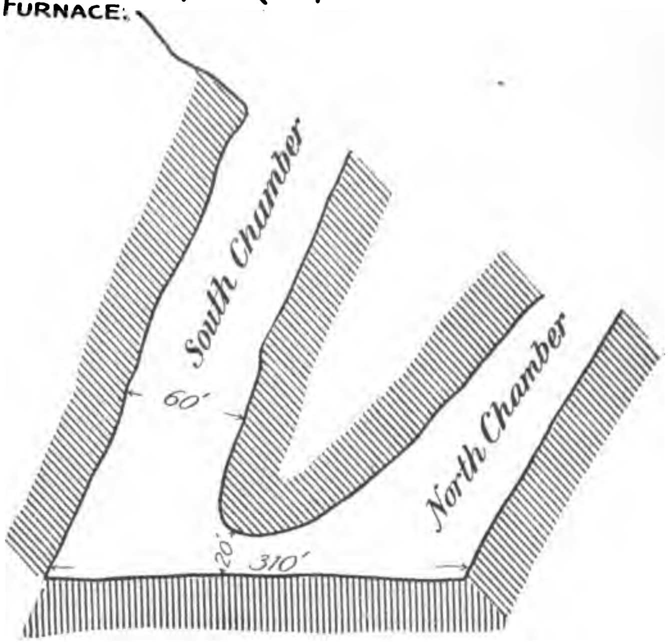
Force-pumps drain the lower levels. An Ingersoll air-compressor furnishes air for operating three drilling-machines. The mining operations have been carried on uninterruptedly for years past.

The New Jersey Zinc Company has not done any mining on their Sterling property, which lies to the northeast of the Passaic Company's mines, for some years past. The workings are kept free from water, however.

FRANKLIN FURNACE.

The Buckwheat or Taylor mine is now 300 feet below surface; the north chamber vein is 70 feet high, and has a depth of 420 feet and a dip of about 27 degrees; the dike of trap-rock which outcrops at surface is found to be persistent in the lower level, and the fold in the vein, dividing the mine into a north and south chamber, continues in these greater depths. The figure below illustrates a cross-section of the vein, showing the division into two chambers.

CROSS SECTION OF TAYLOR VEIN, FRANKLIN FURNACE.



About 2,500 tons of ore per month, which runs about 32 per cent., is the output of the mine, and it is all used at the company's works, in Newark, excepting about 600 tons per month, which is placed upon the market. In addition to the regular mining operations, a crushing plant having a daily capacity of 500 tons is in operation, crushing limestone for use in the Scranton Iron and Steel Company's furnaces, at Scranton, Pa. At the present time 800 tons per week are crushed and shipped.

PARKER SHAFT.

Operated by the Sterling Iron and Zinc Company. The shaft, which was begun in 1891, was sunk to a depth of 950 feet, where it opened upon a body of ore. Drifts along the vein have been driven, opening up the mine for a considerable distance, and the great width of the deposit as found in the old openings to the southwest is here found, only to a still larger extent, and the yield from the workings is consequently large. The plant is extensive, and embraces machinery of the most modern type.

During the past year an extensive concentrating and separating plant has been built by the Wetherell Concentrating Company and the entire product of the mine is put through this mill. By this process the franklinite, garnet, tephroite and fowlerite, and any other smaller deleterious iron and manganese-bearing minerals are separated from the willemite and zincite, leaving the last two minerals in a condition for direct use in the Belgian furnace for the manufacture of a very high grade of spelter metal.

PART VIII.

Notes Collected During a Visit to the Forests of Holland, Germany, Switzerland and France.

BY

JOHN GIFFORD.

Forest of Pinus Maritima on the Dunes of France, near Arcadeon, showing Fire-Lane in front and the Method of Collecting Resin.

Notes Collected During a Visit to the Forests of Holland, Germany, Switzerland and France.

BY JOHN GIFFORD.

It is no doubt indiscreet to publish one's impressions of the forests of such an area, based upon a sojourn of only four months. In so short a time one is little more than able to learn the geography of the regions visited, not to mention the fine methods which are in operation, especially in the State and Communal forests of Germany.

It rained incessantly, rendering tramping in the woods, day after day, fulfilling engagements in spite of the weather, not only laborious but disagreeable, and, on the high mountains, often uncomfortable.

In order to write comprehensively of European forestry methods, one must spend at least six months in at least a dozen centers. These impressions, therefore, are only cursory, and must be re-inforced and enlarged by future visits to these interesting regions. In order to comprehend the development of the subject in Europe one must wade through an immense amount of scientific and historical literature.

We landed in Holland, and then visited the following forest regions: In Germany, the Spessart, the Communal forests of Hesse, and the Black Forest; in Switzerland, the Bernese Alps; in France, the Dunes and Landes of Gascony.

HOLLAND.

Like Southern New Jersey, Holland has its upland, its meadows and its dunes. The most fertile land in Holland corresponds to the Jersey marshes, the "polders" to the salt ponds and shallow bays, the dunes along the North sea to the dunes along the Jersey shore, and the large area of upland or heath to the pine lands and savannas of the

southern interior. There is still in the little country of Holland from four to five hundred thousand hectares of wasteland, which consists of heath, moorland, dunes and morass. An association is at work striving to to develop this waste land. When an important work is undertaken by this society it receives royal approval and aid. Besides this, there are no forestry officials in Holland excepting the Professor of Forestry at the Royal Agricultural College. The young Dutch foresters find employment in the vast colonial possessions. It is encouraging to those interested in similar societies in America to know that the Dutch Heath Society and other societies throughout Europe have been successful in many respects. Much that has been accomplished in Europe is due either directly or indirectly to the work of societies similar to the forestry associations of the United States. The Dutch Heath Society has a membership of two thousand. This association has accomplished a very great deal in the way of encouraging private individuals to improve their waste lands by forest-planting. It has also induced the government to appropriate money for experimental purposes. The appropriation for dune-planting was placed in the hands of this association, to be expended under its direction. In Europe, as in America, it is evident that laws relating to the forests owned by private parties cannot be enforced easily unless the people are interested and willing. Government moneys for improvement of waste lands are entrusted to its care, and expert foresters are employed to give advice and to put into execution whatever may be desired.

An example of extraordinary patience and patriotism may be seen in Holland, on the Schober plantation, at Schovenhorst. Forty years ago this was a barren heath. At great expense thousands of conifers of many kinds were introduced from many parts of the world in order to show the species best adapted to the soil and climate of the heathlands of Holland. Although this huge experiment is still incomplete, it shows what one unselfish, patriotic man can do in the way of demonstrating the capabilities of the soil of his native land.

Only a small part of Holland was ever wooded. In the region of Zeist and Arnhem there are many magnificent groves, while the forest, mainly of European beech, near Scheveningen, the popular sea-shore resort, is famous, having been planted long ago for a royal hunting-ground. In the lowlands of Holland, especially in regions recently reclaimed, there are of course few trees. The willow, the Cinderella of plants, may be seen everywhere. It is used for many purposes—

from serving as mattrasses and wattle-work to protect the dikes to little baskets which are sold for a penny. The fuel used in Holland comes in the form of coals from England, faggots and small wood from surrounding countries. There are also in Holland vast areas of peat, which is used for fuel in place of wood and coal. The lumber used comes from Norway and Sweden, Germany, and to a slight extent from America. The long, straight poles which are used for pilings in the soft mud of the Lowlands come mainly from the magnificent forests of the State of Baden. We left the practically unsettled peat region, called "De Peel," in Brabant and Limburg and entered Germany, the home of forestry.

GERMANY.

In Germany the idea of the perpetuation of the forest is permanently established. Many of the forests are worked according to very elaborate plans, executed by well-trained officers, with scientific exactness. The perpetuation and improvement of the forest, and the betterment of the soil and the construction of roads are always paramount in the minds of those who have charge of the State and Communal forests. An amount equivalent to the increment is cut, so that the forest always remains one of the most valuable of Germany's resources. Although the forests are scrupulously cared for according to very modern methods, the saw-mills are generally crude and the implements clumsy. There is very little waste of material. In Germany much attention is paid to detail. Forestry there is paramount, not even secondary, to agriculture. The chief forester is ruler in his district. He constructs the roads, cuts and plants the forest, lets meadows, gardens and houses belonging to the government in his region; in fact, his duties are many and varied.

Leaving Holland, we rode to Cologne and thence to Giessen and Aschaffenburg, where important forestry schools are located. Thence we traveled to Rothenbuch, a little town in the midst of the famous oak and beech forests of the Spessart. At the little inn we at once learned that Sir D. Brandis, with a class of English students, and Mr. Carey, of Maine, had shortly preceded us. Early in the morning we were surprised to see four hundred pigs and many geese being driven into the forest. This is one of the peculiar peasant rights of the Spessart, which will be referred to later. Here and there near

the town were many small but rich and well-irrigated meadows, which yielded, in spite of the shortness of the season, four crops of hay per annum.

In the northwestern corner of Bavaria, enclosed in a bold bend of the river Main, is a beautiful mountainous forest region known as the Spessart. It varies from 350 to 617 metres above the level of the sea, and is drained by many winding streams. The climate is quite severe and the snowfall heavy, causing considerable damage to the conifers which grow there—the Scotch pine, spruce, and a small quantity of white pine. Oak and beech, however, predominate. Generally speaking, the soil is poor, being mainly a kind of sandstone belonging to the Trias formation. When the soil is exposed, or robbed by the peasants of humus and litter, it will not produce a fine grade of beech and oak. Such land is planted in conifers until it recuperates sufficiently to support the beech. One of the interesting features in the management of the Spessart forests is the encumbrance in the way of peasant rights which have clung to it more or less since 1814, when the dukedoms of Mainz and Würzburg passed to the Bavarian crown. There are rights to litter, to wood, to pannage and to pasture. At one time the peasants availed themselves of these rights to such an extent that the soil deteriorated, and oak and beech in places could not find sufficient nourishment. These rights, however, have been regulated by law.

The principal indigenous trees of the Spessart are the oak (*Q. sessifolia*) and the beech. Many of these oak trees are magnificent specimens, some of which are 500 years of age. These venerable trees formerly stood in ancient pasture-lands. During the "Thirty years' war" the cattle were killed or removed and after the close of the war natural reproduction followed, and what were once pastures have become beautiful forests of oak.

In the Spessart, owing to mistakes in the early management of the woods, there is a comparatively small quantity of oak of middle age and an abundance of pure beech woods. This was due to the fact that regeneration was effected over large areas at one time and that an undue proportion of standards was left. There was not sufficient light to favor the oak, which is quickly crowded out by the beech of about the same age, which grows more rapidly. This difficulty has been overcome by growing the oak in "horsts" or groups and by lopping off and cutting back the beech. Heavy oak masts occur in

Europe about every 6 to 10 years, which is less frequent than that of the majority of American oaks. The beech prevails in the Spessart —in fact everywhere in Germany where it can be successfully produced. It is of little value commercially for anything but fuel, but the Germans are partial to the beech. It is their favorite tree. They point with pride to the forest which almost equals their ideal—it is a forest of oak with clean, straight boles, with a dense underwood of thrifty beech. The oak furnishes material for the construction of casks in which to hold their precious wine and beer, while the beech, by its thick deposit of leaves and dense protective canopy, enriches the soil, conserves the moisture and stimulates the height-growth of the oak. There are no weeds in such forests. The ground is covered with nothing but humus, and the dense shade of the beech prevents the growth of shrubby heaths.

Young white pine is mixed here and there with the beech, although it is generally not highly esteemed in Europe. The silver fir (*Abies pectinata*), which reaches perfection in the Black Forest, is seriously damaged by deer in the Spessart. This difficulty in Baden is obviated to a certain extent by covering the tender tips of the silver firs with linen tow. This tow, which clings to the mouth of the deer, becomes distasteful and monotonous in the course of time, so that he learns to leave the silver fir alone.

The great object in the Spessart is to produce forever a regular yield of first-class oak; to turn these regions into deciduous forests, which, owing to the impoverishment of the soil, by removal of the litter, are now only able to support conifers; to cover the surface with beech, in spite of the fact that firewood cannot be profitably sold in the Spessart, and to grow pine and fir to supply the demands of the region. It is hardly worth while to explain in detail the various methods of regenerating these forests. The following has proved the most satisfactory method: In areas (from 5 to 30 acres in extent) where the soil is good, especially where large, thrifty beeches have grown, acorns are sown. After thinning, when the oaks have reached an age of from forty to fifty years, an underwood of beech is planted. The young beech grows rapidly, the soil is enriched by their leaves and kept moist by their shade, and the oak growth is at once stimulated, resulting in a beautiful and valuable forest. We next visited the Communal forests of Frankfort and Darmstadt.

THE COMMUNAL FORESTS OF THE GRAND DUCHY OF HESSE.

Why do American cities persist in having immense conventional parks? They are little more than large unproductive playgrounds. New Jersey could have a series of communal forests which would answer for parks and at the same time yield a profit. A well-cared-for forest, with excellent driveways, is, in every way, superior to the ordinary American park. Were the cities owning parkland willing to convert these into profitable forests, they would be setting an example of immense value to the State and private individuals, as well as producing the proper sentiment in the minds of their people. As it is, more support to the forestry movement comes from the cities than from the country, and more from the farm regions than from the owners of forest. The forest of Darmstadt, for instance, serves the purpose of a park and at the same time yields an income to the city. With the completion of the system of public parks and parkways projected by the Park Commissioners, Essex county will rank with the largest cities of the world in this respect. The park area will approximate 3,000 acres. Were this as well forested as the Darmstadt parks, it would yield a handsome revenue, and be at the same time much more attractive and valuable than the majority of city parks. This matter is especially worthy of consideration in case the city owns the surface which supplies it with water.

If the region of the Palisades becomes a State or city park and the forest is properly treated, it is more than likely, owing to its location, that it will pay a good interest on the amount invested, improve in quality, and at the same time serve as a place of enjoyment for tens of thousands of people who live within sight of it. The following interesting paper was prepared for "The Forester," under the direction of Ministerialrath F. Mühl, of Darmstadt, on "The Communal Forests of the Grand Duchy of Hesse."

"The Grand Duchy of Hesse, with a total area of 767,859 hectares (1 hectare = $2\frac{1}{2}$ acres) has 244,765 ha. or $31\frac{8}{10}$ per cent. of its area in forest. As to the ownership of these forests, the largest part, viz., $38\frac{4}{10}$ per cent. or 94,218 ha. belongs to the communes, societies and corporations; these figures being double the average percentage for the whole of Germany. $32\frac{8}{10}$ per cent. of the forests are private, and the rest, $28\frac{8}{10}$ per cent., belong partly to the State and partly to the

crown; those belonging to the latter, however, have been confided to the care of the State. Thus the communal forests comprise about 12 per cent. or one-eighth of the entire territory. Their importance to the State as well as to the separate communes is therefore fully apparent. From the earliest times, the communal forests of the ancient Hesse, and of most of her incorporated possessions, have been subjected to forestry regulations. Appreciating the position and significance of the commune in the State organism, as well as the peculiar conditions of forest management, a government regulation introducing the system of forest districts as affecting communal forests was established in 1776, according to which the management of communal and State forests was to be uniform in principle and conducted by the same authorities. An edict in 1803 confirmed the plan, establishing an "Oberförstamt," and especially declared that communal, society and corporation forests should come under its rule and sway. These forestry regulations were, however, not specified in detail nor generally systematized, and this defect was greatly emphasized in the year 1806, owing to the accession of several Princedoms where forestry methods either differed or were entirely absent.

The Organic Forest Law of January, 1811, applicable to the newly-created State of the Grand Duchy of Hesse, corrected this defect; it did not extend, however, to the province of Rhine-Hessen (acquired at the time of the Napoleonic dissolution), owing to the fact that the forestry laws already existing in this province, derived in part from French rule, were already sufficiently analogous in principle. The established methods of forestry management contained in the organic law of 1811 are still, in the main, operative, with the exception of the principle applying to the care of private forests, these having been released since 1819, although they are still subject to the rule requiring re-foresting after cutting.

According to Section 2 of the aforesaid Organic Forest Law, the districts to be known as "Oberförstereien" and "Forste" shall so fit into each other that every spot of ground in the whole Grand Duchy, whether covered with wood or not, shall belong to an "Oberförsterei" and to a "Forst." The Grand Duchy, according to this principle, is now divided into 6 "Forste" and 71 "Oberförstereien" which comprise state, communal and private forests, with boundaries fixed as suitably as possible. The heads of the "Obeförstereien" are called "Oberförster;" those of the Forste, "Oberförstmeister." The ap-

pointment of these officials is made by the crown without reference to the district they are to govern. They must have passed a final gymnasium examination, have studied Forestry for three years at the State University, and have passed the State examination and gone through a practical course. The Oberförster carry out their administration under the control of the Oberförstmeister and under the instruction of the Grand Ducal Ministry of Finance (Department of Forestry and Finance).

According to the law of 1811, the term Communal Forests includes, besides city and village forests, the forests of all societies and corporations. The Department of Forestry and Finance is subordinate to the Grand Ducal Ministry of the Interior. Perpetual and permanent management is the fundamental principle of the whole administration. Technically, this is accomplished (according to ownership rights) through the co-operation of communal representatives with district officials (government authorities). As to the mutual relations of the State Forest and the Communal authorities, Section 37 contains the following: "In the technical treatment of communal forests, the Oberförster do not serve under the magistrates, councilmen and representatives of Communes, but only under the higher State Forestry authorities, whose orders they must closely follow. They must never forget, however, that they are administering the property of others, that their rule must have no other aim than to further the good of the Communes, that they owe the representatives of the Commune respect, if not obedience, and that it is their duty to confer with Communal authorities even about the technical treatment of the forest and to take into account their views and wishes and give information upon any phase of administration when it may be asked for."

Adopting the principle of what is called the "compartment" method, Commune forests are worked on a basis of "cultural regulations," established and renewed every twenty years, the accomplishment of this work being entrusted to the Oberförster and the remuneration paid for out of Communal funds according to a fixed standard.

Forest officials co-operate in carrying out the principles of management and in a revision of the Oberförster's plans, and the approval of the Division of Forestry and Finance as to methods of treatment precedes the fixing by this body of the amount of annual cutting in the sections. In order to hinder any threatened disturbance in the normal condition of forests due to windfalls, conflagrations or insect

pests, or to make up for such losses as are occasioned by unusual demands of owners for payment of debt or other exigency, a reserve amount of growing timber is maintained, *i. e.*, a quantity above the normal supply. Variations from the established amount to be cut, in the way of anticipated cuttings, are only allowed in case of need, occasioned by financial embarrassment, in building school-houses, roads, etc., and only with the sanction of the government authorities, and such additional cuttings are taken into account in the following year's calculations.

The government, however, sometimes even authorizes "extra cuttings" without reference to the following year's supply, and not in strict accordance with economic rules, when circumstances seem to justify them. In all such cases, and where disputes and differences arise among the various authorities, the decision in favor of an extra cutting is only to be made on the principle of keeping in view the lasting benefit to the Commune, and the cutting is to be done in such manner and with all such technical aids as shall minimize the hurtful effects. In order to facilitate a comparison of results with prescribed plans, a revision of the cultural regulations or working plan takes place every ten years. It will be seen that the co-operation of communal authorities in reference to technical management of their forests is only advisory. According to the law of June, 1880, relating to the conduct of Forestry and Communal Bodies regulating Receipts and Disbursements, the Oberförster have to hand in to Communal Board a schedule containing the computed wood receipts and by-products of communal forests for the following year, as well as the computed expenses for choppers' salaries, gathering of by-products, cultural and other works, such as road-building. Special cuttings are to be separately scheduled according to the object for which they are authorized. The schedule, after being passed upon by all communal authorities, is ultimately referred to the "Oberförstmeister" for confirmation. Mayors may be present at a revision of local plans.

Differences arising among authorities as to the schedule of computed receipts and disbursements, the final decision rests with the Ministry of the Interior. Appointment of forest guards or wardens takes place according to the law prescribed in 1811. Aspirants are presented by the Communal Board in question, and when there is no opposition are confirmed by the Department of Forestry and Finance. A dismissal of these confirmed forest guards, on the part of the com-

mune alone, is not allowed. If the several communes are not large enough each to constitute a separate "Forst-Warte" (circle), then the contiguous State, communal and private forests are united to form a circle. If these mixed Warte contain more than 25 ha. belonging to the State the guards are called grand ducal forest guards, and the State has full sway in appointing them. The mixed circles are subdivided into normal forest circles: such as contain more than 150 ha., State forests, and "abnormal"; such as contain between 25 and 150 ha., State forests. The first are paid and pensioned by the State; the second are paid and pensioned by the communes, and the State treasurer only disburses the amount raised by the communes. For the management of their forests the communes pay a fixed sum towards the wages of the Oberförster, the calculation of which is based on the assessed valuation of territory.

The sum total of Oberförster's wages is 266,600 marks, the proportion paid by the communes being 119,933 marks, which is a small sum when the value which communal forests represent in the Grand Duchy is considered. From the report of five years' management (1889 to 1894) the average net yearly income from State forests was 22 marks 79 pf. per ha. The capital valuation, therefore, according to accepted formulas, would amount to 911 marks 60 pf. In the communal forests similar statistical data are not available, but it may be assumed that the average net returns of lands managed in the same manner and under the same control would be equal to the State figures. The valuation of 94,218 ha. of communal forests would therefore be 85,889,129 M., a sum which clearly reveals the importance of these possessions not only to the communes but to the entire State. This valuation is constantly being enhanced. It may be mentioned here that the good condition and large yielding capacity of the Hessian communal forests is chiefly attributable to the strict laws in force for fifty years regarding the use of wood litter, which is not allowed to be gathered for direct use, but which is collected and made up into salable portions and sold at public auction, and the net proceeds divided in cash among those entitled to receive it. The gathering of "wood litter" is restricted to a percentage of the forest area. In coniferous woods, at the utmost 20 per cent., in deciduous woods, 19 per cent. In the year 1893, which, owing to protracted drought, was a year of great dearth, the laws of 1839 regulating these methods of disposing of wood litter were suspended by a law empower-

ing the Minister of the Interior, in case of extraordinary dearth of fodder and bedding, to allow the "wood litter" to be delivered directly. In this case the price is to correspond to the tariff price of State wood litter.

Consider more closely the significance of the communal forests in Hesse. The commune as a political unit for a certain number of State residents in a limited territorial district, to which the individual looks for benefits and advantages, has above all, in order to confer such benefits, to preserve the communal property undiminished for future generations. All speculative tendencies are therefore to be excluded from communal methods. Such a purpose is accomplished by means of ownership of forests in or near the commune. Commune funds are taxed heavily for the ever-increasing demands of a growing population, for maintenance of schools, new schools, improvements demanded by a higher standard of living—such as water-works, lighting-plants, public slaughter-houses, hospitals, etc.; works which cannot be left to the discretion of individuals, but must be entrusted to the communal representatives. To meet all these demands, it is imperative for the communes to know that their revenue shall be certain and lasting. This, also, the forest ensures. The forest stores up a large reserve, which is set forth in the annual official statement, or in times of need supplements the ordinary revenue by means of extra cuttings. Without such aid many communities would have to forego the improvements demanded by the times or else still further burden taxpayers. The development of industrial uses for wood which was formerly consumed as fuel will still further increase the revenue from forests and render profitable their more intense management for an increased output.

Not unimportant also is the revenue from different by-products of the forest. The leasing of hunting-rights, particularly in regions near large cities, or accessible by rail, is a considerable source of revenue. Also the leasing of stone-quarries, sand and gravel-pits give large returns, which, of course, are only accidentally related to forestry when useful materials are discovered in forest districts. Quite considerable, also, are the direct benefits to be derived by residents from forest-products. The so-called "Loosholz" supplies a large part of the fire-wood and in some communities the whole supply. Also, from an economic standpoint, the large quantities of "Leseholz" deserves mention. It is not reckoned in the forest statistics, and in Hesse is

understood to be dry branches blown down by the wind, such as are not used to sell, and such dry wood (not over 6.25 cm. thick) as can be reached from the ground without climbing the tree, and can be broken off by one person. Considering that such brush-wood is utilized only within a limited distance from dwellings, it may be estimated as five per cent. of all fallen wood. This gives as the amount gathered from 94,218 ha. of communal forest at five cubic meters per ha. a total of 23,554 cubic meters wood per year. This practice is politically and socially of peculiar significance, because in many regions the wood thus gathered contributes largely or even wholly to the fuel-needs of the poorer classes. A further product which the forest provides, and in consequence of which communal forests are often sorely taxed, is "Waldstreu"—wood-litter. Its use is sometimes unavoidable, though to the enthusiastic forester it seems a crime, and is often the cause of discord between forest officials and communal authorities, and often has to be denied entirely, owing to cultural need of retaining it. To what extent, however, it may serve to supplement agricultural needs of the poor in years of dearth in straw and fodder was shown in the year 1893, when the former law already referred to was set aside. In 1893, from communal forests, there were harvested 14,000,000 bundles of wood-litter at five cubic-meters. An average of 12.91 per cent. of the entire forest-area was made to yield litter, and in some districts where the dearth was greatest the use of litter extended to 46 per cent. of the forest-area.

Based on a calculation of the comparative value of straw and wood litter, the yield in 1893 was equivalent to 556,452 cwt. of straw, and in truth it was the forest with its litter, its meadows, its supply of dry grass and foliage fodder, which enabled the people to tide over the bad season referred to. Of course, as a consequence, and in order to heal the wounds occasioned by these inroads, the following years are devoted to protection and restoration. Still further to be mentioned are the supplies of wild berries, a considerable yearly help to the poorer classes.

Consider the wages of labor connected with the culture, exploitation and transport of forest products which accrue to the commune residents. The average State expenditure in five years (1889-1894), for wood-choppers' wages, including expenses, applied to the 94,218 ha. communal forests results in wages received amounting to—

Wood-choppers	863,036 M.
Cultural expenses	201,626 "
Road construction	236,487 "
Other expenses	146,037 "
Total	1,447,186 M.

Cost of transport is another considerable item. Danckelman estimates the wages for wood transport in all Germany at 51,000,000 marks annually. The communal forests of Hesse would therefore yield to wood-haulers 344,837 M. yearly, a total income to wage-earners in Hessian communal forests of 1,800,000 M. annually. If it is further considered that the forest labor occurs mostly at a season when many industries are idle, when field-labor is not possible and the outlook for other earnings is very slim, the benefits derived from the communal forests appear in a twofold light. How many classes are also employed in the numerous industries dependent on forest products? And human ingenuity is daily increasing the number of uses for wood-products so that the presence of a forest often determines the type of a whole community. The earnings derived by a given district from the forest not only increase its revenue but add purchasing power which is felt beneficially by other districts. As to the indirect value of forests from a hygienic point of view, their influence on soil and temperature upon moisture of the atmosphere and evaporation, upon the frequency of rainfall and the volume of springs, as well as their protection against raw winds, the facts are well known. The proper recognition of the great importance of forests in the economy of nature and of States has led indeed to the establishment of forestry regulations.

In Hesse, the extent of whose communal forests is only exceeded in Baden and in Elsass Lorraine, these beneficial effects are very noticeable. In general it may be said that the Communal authorities of Hesse fully recognize the importance and significance of their forests. In parts of the State where the woodlands still largely belong to private peasant proprietors they are disposing of them, partly from financial stress, partly from a conviction gradually gaining ground that ownership of woodland more properly belongs to the State or Commune. Thus large areas are being gained by the Communes. This is also the case with land still under cultivation, but which, owing to distance from markets, difficulty and unprofitableness of transport, is only fit for forests. A similar process is going on in the province

of Vogelsberge in Upper Hesse. The comparatively well-wooded lower portions of the province belong mostly to the State and only a small fraction to the Communes, while of the upper unwooded portions, the poorest and most distant districts, two-thirds belong to Communal, one-third to private owners. This considerable area owned in common, consists mostly of pasture-fields with a small amount of poor farming and meadow lands, which are, however, in reality all pastured. This results in the inhabitants keeping an abnornal quantity of cattle, which in years of drouth, as 1893 most sadly proved, cannot be supported. This disproportionate tendency to agriculture is the reason for the lack of prosperity among the inhabitants of Upper Vogelsberg, and the fact of a false balance between wood and farm land, the fact that where lusty wood-crops should be growing there are bare and desert grass-lands, accounts for the unfavorable climatic conditions of this region. As Forstassessor C. Weber in his excellent work has undubitably demonstrated, all these evil conditions in Vogelsberg would be overcome by exchanging the pasture and waste spaces for woods, and an almost entirely unproductive area would be made productive. It will, indeed, take a long time for this rural population, so stubbornly wedded to old accustomed ways, to attain the proper standard, but a beginning has been made. In a number of the districts of Upper Vogelsberg there are every year certain lands re-forested, because of climatic difficulty and expense of other cultivation. The State in such cases, recognizing the importance of the subject, lends aid. In the State budget quite considerable sums are set aside to defray half the cost of re-foresting undertaken by such communes.

In closing, a further benefit may be mentioned accruing to small communities and large cities as well, from the ownership of forests. In our age, where nervous maladies make such alarming inroads, it becomes a necessity for many to retire at times from the heat and burden of the day. There are regions whose heights are covered with lovely woods, where the fresh, fragrant forest air acts as a restorative to worn-out body and mind, and incites to summer excursions, the ever-extending net-work of railroads opening up each year new regions. Thus the Odenwald, with its charming heights and valleys, affording changing views, has become a goal for health and pleasure-seekers, and many a little place with beautiful woodland surroundings formerly but sparsely visited, has now become a famous resort. The

city of Darmstadt, surrounded by forests of pine and oak, is becoming more and more a favorite home for rich and well-to-do families. In the case of such forests, of course æsthetic as well as financial considerations must prevail. That an interruption in business routine notably contributes to the economic welfare of citizens and by increasing their power of producing thus in the end benefits all classes, hardly needs to be especially mentioned. In summing up the foregoing considerations we must admit that the communal forests play an important role in the policy of communes, and that their preservation is greatly favored by the principle of a common ownership. The proverb is here verified:

"Den Wald zu pflegen
Bringt allen Segen."

THE BLACK FOREST.

At least some of the features of the Black Forest method of treating mixed, irregular woods can be easily and inexpensively applied in America if the owners of large tracts of land would employ able foresters instead of mere managers.

The Black Forest is a mountainous land of beautiful evergreen woods, with fertile valleys and rich, carefully-irrigated meadows. The upper strata are not fertile, being a coarse sandstone similar to that of several mountain ridges in northern New Jersey; unlike them, however, in that fire is almost impossible and the forests are well cared for in the Grand Duchy of Baden. The great beauty and healthfulness of this forest region attracts many tourists and invalids. The European chestnut, beech, maple, ash, two varieties of oak, the mountain pine, the Scotch pine, the spruce and several American trees are common there. The most beautiful, however, is the silver fir (*Abies pectinata*), with its long, straight boles, many of which are used for pilings in the soft mud of the Netherlands. Although of great interest, time and space at present only permit of a very short description of these extensive forests.

Baden is the home of an excellent system of natural regeneration. In many parts of Europe the forest is divided into sections. Each section is planted and cut at a certain time. The young trees, usually of one species, such as *Pinus sylvestris*, are grown in nurseries and then transplanted. This method, although simple and

similar to farming, has many disadvantages. A mixed forest is always healthier and never so seriously troubled by insect pests. Trees are healthier and grow more rapidly when not transplanted. The surface is always covered with forest and never exposed to the beating force of wind and rain or the scorching effect of the sun. The Baden method, wherever it is possible, is the cheapest and most scientific way of treating mixed, irregular woods such as predominate in America. The total area of Baden is 5,800 square miles or 1,508,113 hectares, 550,656 of which are in forest. The percentage of cleared land to uncleared land is about the same as that of New Jersey. Of the forest area 92,267 hectares belong to the State, 4,779 to the crown, 251,460 to communes, 182,885 to private individuals, and 19,265 to societies. One is impressed with the fact that only an amount equivalent to the increment is cut and a large percentage of this consists of wind-falls and timber which has become diseased. In many places much more could be cut with advantage to the forest, but the *axe is cautiously used and always with a purpose beyond the simple reaping of a wood crop.* Much more attention is paid to quality than quantity. The Black Forest saw-mill, although common everywhere along mountain streams, is not a voracious instrument of destruction. With old-fashioned up-and-down saws it works slowly but economically the well-earned increment. It is an essential part of these busy little valleys where agriculture, forestry and manufactures are evenly balanced. The Baden forester plants with the axe, that is, by a certain skillful method of cutting, the forest yields an income constantly, and at the same time, improves in quality. A forest properly treated in this way is very beautiful, an improvement in fact on the natural woods.

It requires, however, a great deal of skill and a perfect knowledge of the species with which one is dealing. One of the secrets of this system is to know just how the different species disport themselves in varying quantities of light, since the amount of light determines the amount of seed and the kind of young growth which follows. The light-demanding and shade-enduring kinds are grown together, and here, as elsewhere in Europe, the beech is a famous underwood. The productivity of the forest is held at its highest mark by the application of ingenious methods, the result of long years of careful observation and experimentation. After a visit to these magnificent and profitable forests, no one can refrain from reproaching the American

people, the possessors of such extensive natural woods, for their recklessness and maliciousness. The forest area in America is not too large, were *the owners content with cutting the increment, instead of glutting the market and cheapening the article by working the principal.*

Our lumbering operations are systems of robbery, our recklessness with fire a crime in comparison with the treatment of the forests of Baden, where the light and shade conditions of every species are carefully studied, and where the delicate and intricate workings of nature are in the hands of the forester, who almost dictates the kind of seed which must fall and the kind of tree which must grow in the spot he has prepared for it. All this at present seems out of the question in America, and we must devote ourselves to protecting the forest which is left, leaving the waste-lands to wait their turn or to improve slowly under the processes of nature.

In the region of Badenweiler, an attractive resort in the Black Forest (Schwarzwald), there are extensive forests of oak and beech, similar, if not equal, to those of the Spessart. There is no place in all Europe where forestry can be more advantageously studied than in the Black Forest (Schwarzwald.) The person who knows thoroughly the methods in practice there is well equipped with the latest and most practical thought on the science of forestry. We reluctantly left Badenweiler and ascended the Belchen, one of the highest mountains in Baden. It was the first clear day in many weeks. Away to the west was the broad fertile valley of the Rhine, at our feet the dark, dense forests and cultivated valleys of the prosperous Black Forest, and away to the south, mingling with the clouds, the snow mountains of the Bernese Oberland were visible.

SWITZERLAND.

It is often remarked that forest regulations cannot be enforced in a country where there is much individual liberty. In disavowal of this the Germans point to their neighbor, Switzerland, which is, in every sense of the word, a republic. In the beginning, forest regulations were bitterly opposed by the Swiss peasants, because the goats and cows, upon which they depended for a livelihood, were prohibited from roaming in the regions set aside for reforestation. In one place the foresters were pelted with stones by the peasants; but public opinion has rapidly changed, and the evil consequences of destroying the forest cover are now understood. Switzerland has accomplished more than is usually

supposed. This may be due to the fact that much of the work which is difficult and expensive is in inaccessible places and seldom visited, except by those who, with foresters for guides, have strength and nerve enough to climb extremely precipitous mountain-sides. It is a constant struggle against the intensified forces of nature. Engineering works, which have been constructed at great expense, may be swept away in a minute by flood or avalanche. Every bit of pasture which is turned into forest deprives some peasant of a part of his livelihood. The available agricultural land is so small that protection, on the other hand, is necessary against the destructive forces of nature which are let loose by deforestation. There are strong winds, avalanches, landslides and floods. None of these, however, are more destructive than the tens of thousands of goats upon which a large part of the Swiss population is more or less dependent.

No nation has suffered more from the effects of deforestation, in fact the safety of a large part of the population depends upon the forest. In many places, by persistent work, the Swiss engineers and foresters have prevented whole mountain-sides from slipping and huge masses of rock from crushing the villages in the valleys. Their boisterous streams, which are fed by perpetual snow, must be constantly watched and the young forests planted on the mountain sides are in danger of ruin by avalanches. Everywhere, in fact, they are persistently wrestling with forces which are far more serious and uncontrollable than American conflagrations. By walls of stone, wattle-work and a host of ingenious devices, they chain these forces until the trees they have planted can gain a footing and hold the rocks and soil in place. There are fields in the valleys almost completely covered with huge stones which have been started by wind, water or frost, and have bounded many hundred feet down the mountain-sides. Unexpectedly in the night the natives have been injured by stones crushing through the roofs of their chalets. This has all been stopped by constructing immense breastworks and planting such trees as the alder, and the peasants now live in safety. Whole mountain-sides have thus been forested, and away up on the mountain tops, in the home of the chamois, where the avalanche is heard, the foresters are experimenting with trees which will grow in high altitudes. *Pinus cembra* is indigenous to these regions. Beautiful forests of beech and larch formerly existed in Switzerland, the cutting of which was a fatal mistake. It has been an expensive but fruitful lesson—one which should be sufficient for the whole civili ed world.

There will never be need of such work in New Jersey, owing to the absence of precipitous mountains, but there is no better place in the world than Switzerland to study the influence of the forest in lessening in many ways the destructive forces of nature. We took the train at Geneva, crossed France, which looked bare and depleted in comparison with Germany, and in forty-eight hours arrived at Bordeaux and the region of the Dunes and Landes of Gascony.

FRANCE.

THE DUNES AND LANDES OF GASCONY.

One of the most instructive and successful results of a combination of engineering skill and forest planting for the reclamation of waste land may be seen in the Dunes and Landes of Gascony. In the early part of this century the condition of this territory, which is bounded on one side by the rivers Gironde and Garonne, on another side by the river Adour and on the other by the Bay of Biscay, was in brief as follows: There were miles of marshy, treeless land, covered with a low but dense growth of herbage. It was unhealthy, with but few roads and was very sparsely inhabited. Even to day, now and then, one of the old-time peculiar and picturesque shepherds may be seen watching his flocks, standing on stilts, wrapped in a woolly sheepskin coat, knitting stockings. It was, in short, a desolate, little known and unproductive country. The ground being perfectly level, sandy and underlain with a peculiar hard pan called *alios*, was poorly drained. There was fever in consequence. *Ali s* is a sandstone, the cementing material being organic matter and compounds of iron similar to the ferruginous sandstone of South Jersey. Near the shore there were salt ponds, fresh lakes and stagnant marshes. Bordering the sea for miles there were huge masses of moving sand called the Dunes. These dunes arrayed themselves in lines along the shore, moving constantly inland, covering villages, filling rivers and clogging inlets. This aggravated the unwholesome condition of the territory in their lee called the Landes. Early writers state that the sandy Dunes and the marshy Landes were both at one time forested, and that this dangerous condition of affairs was the result of imprudent forest destruction. Imagine the dunes along the Jersey shore clogging up the inlets, the water from the interior flooding the marshes and lowlands. The bays, which are now salt, would then become fresh in consequence,

stagnation and sickness would follow, and you would have an exact repetition of what happened in Gascony, all of which is described in detail in the works of Chambrelent, Bremontier and Grandjean. The first and most important step was to stop the shifting sand. This was in part accomplished by covering the surface with brush and then sowing the seeds of the maritime pine (*Pinus maritima*), and finally in full by the construction of an artificial littoral dune. When the tide falls the sand of the beach, ground into powder by the waves, dried by the sun and wind, is blown in the direction of the prevailing winds, which is usually toward the shore. The sand moves like drifting snow until it meets an obstruction, and there a dune is formed equal in height to the height of the obstacle. In order to protect the natural dunes which have been sown in pines, an artificial or littoral dune is constructed. This is accomplished in a very simple but ingenious way. A fence of boards or brush is built in a line along the shore a short distance from high-water mark. This stops the sand which is moving inland, so that a drift forms similar to snow along a hedgerow. When the sand forms a drift equal in height to the fence, so that the fence is in fact buried, a new fence is constructed on the crest of the dune which has just been formed. So on fences are buried and constructed until the dune reaches the desired height, and if lacking in breadth or too wide, the fence is moved back or forward a little to suit the desires of the forester or engineer in charge. By the use of palisades or brush an artificial dune can be easily and cheaply constructed. The dune should have a gentle slope toward the ocean. When the dune has reached the proper size and shape it is necessary to plant its windward slope in *gourbet* in order to hold the sand in place. The *gourbet* or sand sedge (*Calamagrostis arenaria*) is common also on American dunes. This plant has rhizomes many feet in length, by means of which it fixes the sand. This huge bank of sand is constantly watched and kept in shape.

In traveling along the beach from the mouth of the Garonne to the mouth of the Adour, one sees squads of men and women working on this immense ridge of sand, planting gourbet here and there or digging it up in places in order to keep the dune in perfect shape. The vast plantations of pine and the villages in the neighborhood of the dunes owe much to the humble but persistent gourbet. Where were once nothing but huge, barren, shifting dunes are now beautiful pine forests close to the shore of the ocean—the location of several delight-

ful resorts, with the pleasures of the sea and forest combined. Back of the dunes in the Landes, canals and drain-ditches were dug through the impermeable alios. Pine seeds were sown, and, through the efforts of engineers and foresters, the region changed to such an extent that a new province was really added to France. The Hugue method of turpentine-orcharding was adopted, the main principle of which is to prevent excessive bleeding. The cut is never more than the tree can bear, unless it is ready for timber, and the turpentine drips into a little vessel similar to a small earthenware flower-pot.

Bled timber is unanimously considered superior to the unbled, and Frenchmen cannot understand why there is a prejudice against it in America. Many rail and wagon roads were constructed, and immense quantities of timber go to England. Rosin and terebenthine are manufatured in large quantities, and fuel is shipped to the bakers in Paris.

With the advent of railroads forest fires increased, requiring the construction of fire-lanes and the employment of watchful wardens. The soil and people improved, and, thanks to de Villers, Bremontier, Chambrelent and others, the Landes is one of the most interesting and prosperous regions of France.

Along the coast of America there are shifting dunes. At Avalon, New Jersey, a huge bank of sand is slowly but surely destroying a beautiful forest. It could be stopped at slight expense. These dunes are moving inland over the marshes, leaving their natural beds so that the marsh mud is exposed on the ocean side, and the beach becomes unfit for bathing purposes.

Destroy completely the forest which covers the southern portion of the State of New Jersey, and it will become a bed of shifting sand, unproductive, unsightly, and unfit for habitation, although capable of producing an abundance of valuable timber.

The illustration which accompanies this paper shows the forest, the collectors of rosin, and the edge of a fire-lane on the Dunes of France. Compare this with the shifting dunes of Avalon or of Cape Henlopen.

CONCLUDING REMARKS.

The social, economical and political conditions of the United States and Europe are so different that it is impossible, at least at present, to enforce regulations here which are enforced with difficulty in Germany and France. One can sift, however, from their methods valuable

points, or receive suggestions, which can be applied with more or less profit to the peculiar conditions of parts of the United States. At any rate, the rudiments must come from the old world, enlarged or modified to suit American conditions.

Few States have been more thoroughly deforested than New Jersey. Just how to mitigate this evil without the expenditure of large sums of money and without infringing upon private rights, or without adding to the expense of those who are already burdened by unprofitable land is, indeed, a difficult problem upon which there is naturally great diversity of opinion. After a visit to several of the principal forest regions of Europe, where the forest officials spared no effort to explain their methods, and show their errors as well as successes, the writer believes that great caution is necessary in this work, and that what is gained must come little by little until America has, after much experimentation, developed her own systems applicable to her varied climate, species, soils, and demands. Forest-planting, timber-culture, insect and fungous pests are at present of secondary consideration only. The first and most important steps are the prevention of conflagrations and the construction of roads in forest-regions. After a visit to the pine and cork forests in Var and the extensive pine-forests in the Landes of France, where large areas have suffered from the effects of fire, in spite of the value of wood and the attention the subject receives, one is convinced that too much caution cannot be exercised in formulating laws and expending cash. The writer is positive, nevertheless, that fires can be prevented or reduced to a minimum in the course of time in southern New Jersey at comparatively slight expense. When fires are stopped improved methods of cutting can be easily applied. The most important step is to protect the forests which already exist, then to improve them in a way similar to the method in practice in the irregular woods of the Grand Duchy of Baden, and then finally to reclaim and plant the waste lands. In reference to forest lands owned by the Federal and State governments there is absolutely no good reason why they have not been properly protected and exploited, even if the profits have not been sufficient to meet expenses. It is apparently due to the selfishness, indifference or ignorance of those who have the power to change the state of affairs were they so disposed. In a State, however, such as New Jersey, which owns no forest land, the problem bristles with difficulties. Selfish corporations, impatient and dis-

couraged forest-owners and unpatriotic citizens must be converted, persuaded or forced to accede to just regulations, which may be formed for the benefit of all. In a region where the forest is wholly owned by private individuals, in a country where every person cherishes his liberties, progress in forestry must be gradual.

In Germany it requires constant attention to keep the peasants from overstepping their rights. In the regions where the most scientific methods of silviculture are in operation, where plans have been arranged which extend beyond this and the coming generation, the State has purchased absolute control. In several communal forests the foresters have been unable to accomplish as much as they desired because of the interference of certain peculiar peasant-rights. They persist in driving their cattle, hogs and geese into the forest and in collecting faggots and leaves at stated intervals. In spite of the private ownership of forest-land there is hope for New Jersey. It possesses a great variety of useful and rapid-growing species of timber trees; natural regeneration, when the soil is not too seriously damaged by fire, is prompt and vigorous; means of transportation are good and rapidly improving; large cities are near at hand for markets, and only a small proportion of the people are hopelessly ignorant. In spite of soil-depletion occasioned by fires, a German forester would no doubt regard the replacement of the pines by oaks—even if of a scrubby nature—a favorable trade. After fires have been stopped, all that is needed is care in the use of the axe, so that the forest will improve in quality instead of deteriorate, as under the old-fashioned method of cutting.

In order to reach the most desirable class in America, that is, the class which works the forest and handles its products, the profit which will result from the proper treatment of the forest must be clearly proved. Were one to demonstrate to a business man that he could, without difficulty, reap an interest of six per cent. from his forest for fifty years and at the end of that time have a forest superior in quality and worth ten times its original value, he would disregard it. The most convincing argument would be insufficient, because the forest, if at all inflammable, is in danger of destruction at least five months in every year, without the faintest hope of recovering damages in case it is burnt. The forest fire is a formidable foe, but no worse than the dreaded avalanche, immense land-slides, and impetuous torrents which the Swiss and French have harnessed by engineering skill

and the planting of trees. The prevention of fires is a small task compared to the fixing of the immense masses of moving sand along the shores of the bay of Biscay, which buried villages in its course. Although these sands are covered with pines, fires rarely, if ever, occur on these dunes, thanks to the few railroads, the many clean fire-lanes and constant watching on the part of the wardens. On private holdings, however, they are not infrequent. The following is quoted from a letter recently received from a French forester in the Landes: "The maritime pine plantations are exposed to a certain number of enemies which cause great ravages. Danger from these sources is always most in plantations of a single species. Against fires only *preventive measures* can be employed. With this object in view, a system of parallel and transverse fire-lanes has been created, composed of forest paths ten metres in width, cleaned to the pure white sand every three years. The amount of woodland comprised between two parallel and two transverse lanes is about one hundred hectares. If a fire breaks out it is of course at once extinguished and the burnt area is encircled with a ditch, the burnt pines being almost always attacked by a fungous disease of the roots. The ditch prevents the spread of the disease and is always resorted to whenever the pines are thus affected. Even the smoke from the chimney of a woodman's cabin is injurious to the trees which are near it."

In order to bring about a change in the treatment of our woods, there must be concerted action of all concerned. Were the State to do its part, the railroads and people their part, there would be no fires except those caused by unavoidable accident and lightning. The number would be reduced to at least ten per cent., and many of these would be extinguished without doing much damage.

Forestry which does not pay is not good forestry. Planting of waste lands after the system employed in parts of Europe is entirely too expensive to be considered at present. Where land is so cheap and natural regeneration so rapid and vigorous, planting is unnecessary. The most important work is to protect the forests which remain, and to apply to these a simple method of improvement-cutting.

Although it is the unanimous opinion in New Jersey that something is needed, there is great diversity of opinion as to just what measures should be adopted in order to protect the forests. Some recommend the appointment of a permanent forestry commission to

attend to all matters relating to forestry; others the purchase of a forest reserve; others wide fire-lanes along railroads and wagon roads; others fire wardens; others the continuance of investigations; others lecture courses in all our public institutions and the distribution of reliable literature on the subject; others the apprehension and conviction of malicious and careless fire-setters; others a rebate in taxes to all who plant or properly protect their forests, and so on. It is needless to say, that all these suggestions have merits and that any one of them which is carefully inaugurated with proper machinery for its enforcement and continuance would do an immense amount of good.

A visit to the forest regions of Germany impresses one with the importance of good roads. Every forester understands road construction. It is one of his most important duties. Forest exploitation and road construction go hand-in hand, so that inaccessible forest regions become profitable solely through the construction of excellent roads. It probably costs as much to cart a large log ten miles over a sandy road in southern New Jersey as it does to bring another log of the same size and perhaps superior quality by rail from distant regions. In Germany excellent stone-roads penetrate the forest in almost every direction. The importance of roads is well illustrated also in France. In certain regions wood is a precious article, in fact there is much inconvenience, if not suffering, in consequence of a lack of it. A few grapevine twigs a day must serve a family for fuel, while not far away, on the shores of the Bay of Biscay, immense quantities of excellent wood is allowed to rot, simply because a lack of roads renders its transportation unprofitable. South Jersey is fortunate in having exhaustless quantities of gravel, which is excellent road material. The new State road, forty feet in width, from Philadelphia to Atlantic City, will be of great service in the transportation of cord-wood. This, it is hoped, is the first of a series of wide roads which will divide the pine regions into compartments. If cleared of brush along their sides, they will prevent the spread of fire and serve as a vantage ground in combatting it. As in parts of Europe, one man should have charge of a certain section of road. He should patrol his portion, *constantly mending the small breaks before they become serious, and at the same time keeping the side of the road free from combustible matter,* and extinguishing or reporting fires before they become uncontrollable. The two most important steps in Southern New Jersey are, then, the construction of wide, well-cared-

for roads and the prevention of fire. Since, as has been already said, forestry is not good forestry unless it pays, and since it cannot pay without the proper means of transportation and a certain amount of assurance against fire, it is evident to all that the efforts of the State, of associations and of all private individuals interested in the subject must be aimed in that direction. The fire question must be grappled with, otherwise the meagre forests which remain will be destroyed and larger areas will become not only unproductive but sterile, without the hope of forests, little better in fact than a bed of shifting sand. One point is worthy of much emphasis in this connection. When a large area of land is by constant cutting and burning rendered bare and barren, there are certain conditions of the soil and atmosphere which vanish with the forest. When the forest once loses its hold it often requires years of toil and great expense to re-establish it. This has been demonstrated again and again in Europe. There is great need of the enforcement of proper laws relating to fire-lanes along railroads and the use of the proper kind of spark-arresters on locomotives. There is no longer any doubt of their efficiency. An experiment was tried in France in a region where rapid trains set continual fires during the dry season. Between the years 1883-1892 forests to the amount in area of 48 hectares were destroyed, with a consequent loss of timber valued at 32,000 francs. Fire-lanes three meters wide were built each side of the lines, at twenty or thirty meters from the tracks, and every fifty meters paths one and a half meters wide were surveyed at right angles to the lanes, extending between the lanes and the tracks. The paths were kept free from vegetation during the dry season. The cost of maintenance, which includes the cost of constructing the lanes and the labor of cleaning the path, amounts to 235 francs a year. Since the application of this plan, damages which previously amounted to 3,195 francs a year, were reduced to less than twenty francs a year. The figures speak for themselves. The so called lanes along almost all the railroads in southern New Jersey are not lanes at all. In many instances they are covered with dry, inflammable grass and brush. A lane, to be effective, must be some distance from the track and must be kept perfectly clean. If it is not possible to make the lanes wider, they should be at least ploughed along their outer edge. The punishment of all corporations, malicious and careless individuals guilty of setting fire

should be more severe and better enforced. With wide roads to serve as fire-lanes, with men to patrol them at all dangerous times, the percentage of fires will be somewhat reduced.

The encouragement by the State of individuals owning forest land, in the way of allowing reductions in taxation on the land in question, provided they improve it under directions, has been and is still successfully applied in Europe. The co-operation of game associations is also important. Large sums are received annually by leasing the hunting-rights, under certain restrictions, in the forests of Germany. And so on, one could write indefinitely of the suggestions which come to one after even so short a visit to the forests of Europe. In conclusion, let me quote the words of Mr. Carey, of Maine, who recently visited the forests of Baden:

"The states and nobles supported the work. Scientists labored and managers experimented. Forestry schools were established to spread through the land the knowledge of what had been gained. Finally, they piled up a mass of exact information about trees and everything related to their life, and established a system of forest management based thereon that is one of the finest monuments of the thoroughness, the conservatism and the patience of the German race. And to-day the forest stands as one of the prime objects of the people's regard, a source of health, wealth and national independence."

Mineral Statistics.

Iron Ore.

	Gross Tons.
The output of iron ore amounted in 1896, according to the statistics reported by John Birkinbine, special agent of the United States Geological Survey, Division of Mining Statistics, to......	264,999
The total production, as gathered from the shipments of the several railway companies which carry iron ore from New Jersey mines, and reported to the office of the Geological Survey, was........	262,070
In 1895* the total production of iron ore in the State, as reported by Mr. Birkinbine, was........	282,433
And the total shipments for the same year........	276,873

These figures show a decline of about six per cent. in the production. Comparing the production of 1896 with the statistics as given in the table below, the decline is noted as small, going back to 1893. The statistics reported in this table are from the shipments of the railway companies and the production of mines whose ore is used in furnaces in the State, but is not carried on any railway line. They are re-printed from the annual reports of the Survey.

Zinc Ore.

The total production of zinc ore in the State for the year 1896, as reported by J. A. Van Mater, superintendent of the Sterling Iron and Zinc Company, is as follows:

	Tons.
Total untreated ore shipped from Mine Hill	58,669.61
Total separated Franklinite........	10,796.83
Total Willemite and Zincite	4,896.76
Total zinc ore shipped........	74,363.20
Zinc ore shipped from Sterling Hill........	3,717.70
	78,080.90

* No mineral statistics were published in the Annual Report for 1895.

The statistics from annual reports of the Geological Survey are here reprinted.

IRON ORE.

1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	
1877	315,000 tons*	
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,169 tons	" " "
1890	552,996 tons	" " "
1891	551,358 tons	" " "
1892	465,455 tons	" " "
1893	356,150 tons	" " "
1894	277,483 tons	" " "
1895	282,433 tons	" " "

ZINC ORE.

1868	25,000 tons†	Annual Report State Geologist.
1871	22,000 tons	" " "
1873	17,500 tons	" " "
1874	13,500 tons	" " "
1878	14,467 tons	" " "

* From statistics collected later.

† Estimated for 1868 and 1871. Statistics for 1873 to 1890, inclusive, are from reports of the railway ompanies carrying the ores to the market. The reports for 1890, 1891, 1892, 1893 and 1894 were from the companies working the mines.

1879.........21,937 tons	....	Annual Report State Geologist.
1880.........28,311 tons	....	" " "
1881.........49,178 tons	....	" " "
1882.........40,138 tons	....	" " "
1883.........56 085 tons	....	" " "
1884.........40,094 tons	....	" " "
1885.........38,526 tons	....	" " "
1886 ....43,877 tons	....	" " "
1887.........50,220 tons	....	" " "
1888.........46,377 tons	....	" " "
1889.........56,154 tons	....	" " "
1890.........49,618 tons	....	" " "
1891 ....76,032 tons	....	" " "
1892.........77,298 tons	....	" " "
1893.........55,852 tons	....	" " "
1894.........59,382 tons	....	" " "

Publications.

The demand for the publications of the Survey is continuous and active, and several of the reports are out of stock. So far as possible, requests are granted by giving the reports to such requests.

The sales of the topographic maps are slightly larger than in 1895. The amount realized by these sales for the fiscal year ending October 31st, 1896, was $450.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports, in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed largely by members of the two houses. Extra copies are supplied to the Board of Managers of the Geological Survey and the State Geologist, who distribute them to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat. Several of the reports, notably those of 1868, 1873, 1876, 1879, 1880 and 1881, are out of print and can no longer be supplied by the office. The first volume of the Final Report, published in 1888, was mostly distributed during the following year, and the demand for it has been far beyond the supply. The first and second parts of the second volume have also been distributed to the citizens and schools of the State, and to others interested in the particular subjects of which they treat. The third volume is now being distributed from the office of the State Geologist. The fourth volume is in press. The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of editions that are now out of print. The publications of the Survey are, as usual, distrib-

uted without further expense than that of transportation, except in a single instance of the maps, where a fee to cover the cost of paper and printing is charged as stated.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY, Newark, 1868. 8vo, xxiv. + 899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins, colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo, viii. +381 pp., with map. Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph. D. New Brunswick, 1881, 8vo, xi.+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi.+439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part 1. Mineralogy. Botany. Trenton, 1889, 8vo., x+642 pp.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo, x +824 pp.

REPORT ON WATER-SUPPLY, by Cornelius Clarkson Vermeule. Vol. III of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi.+352 and 96 pp.

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paleontology, Vol. I.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each 27 by 37 inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of 1 mile to an inch.

No. 1. *Kittatinny Valley and Mountain*, from Hope to the State line.
No. 2. *Southwestern Highlands*, with the southwest part of Kittatinny valley.
No. 3. *Central Highlands*, including all of Morris county west of Boonton, and Sussex south and east of Newton
No. 4. *Northeastern Highlands*, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. 5. *Vicinity of Flemington*, from Somerville and Princeton westward to the Delaware.
No. 6 *The Valley of the Passaic*, with the country eastward to Newark and southward to the Raritan river.
No 7. *The Counties of Bergen, Hudson and Essex*, with parts of Passaic and Union.
No 8. *Vicinity of Trenton*, from New Brunswick to Bordentown.
No. 9. *Monmouth Shore*, with the interior from Metuchen to Lakewood.
No. 10. *Vicinity of Salem*, from Swedesboro and Bridgeton westward to the Delaware.

No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16 Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch.

The maps comprising THE ATLAS OF NEW JERSEY are sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. Payment, invariably in advance, should be made to Mr. Irving S. Upson, assistant in charge of office, New Brunswick, N. J., who will give all orders prompt attention.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo. 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp, with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 18[illegible], 8vo., 41 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo, 199 pp, with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+ xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo , 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo , 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo , 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii.+270 pp , with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x.+368 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x.+452 pp , with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x.+304 pp., with geological map.

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl +198 pp., with geological map.

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897.

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